COMPUTERS

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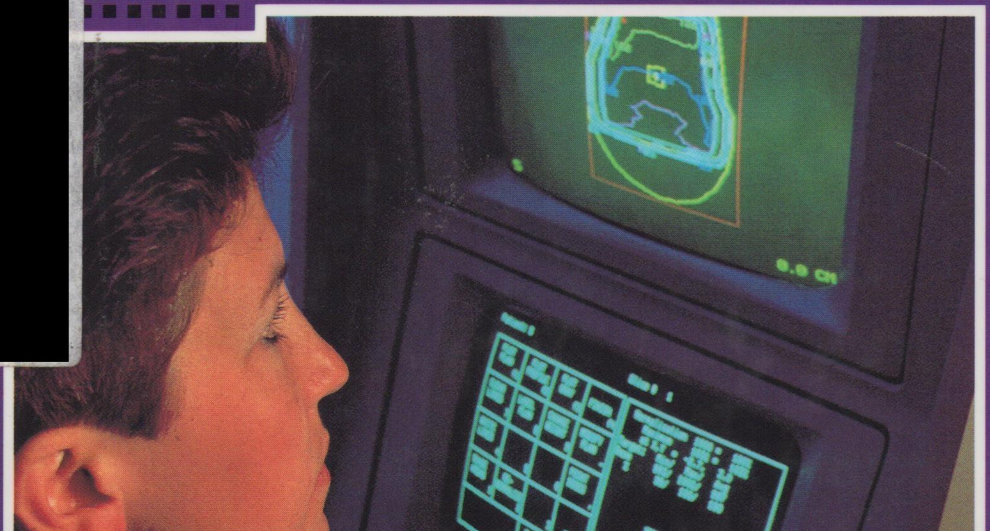
Mechanical Minds



The ENCYCLOPEDIA of
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Mechanical Minds

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COMPUTERS

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Mechanical Minds

by DON NARDO

The ENCYCLOPEDIA of
D·I·S·C·O·V·E·R·Y
and INVENTION

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Foreword

The belief in progress has been one of the dominant forces in Western Civilization from the Scientific Revolution of the seventeenth century to the present. Embodied in the idea of progress is the conviction that each generation will be better off than the one that preceded it. Eventually, all peoples will benefit from and share in this better world. R. R. Palmer, in his *History of the Modern World*, calls this belief in progress "a kind of nonreligious faith that the conditions of human life" will continually improve as time goes on.

For over a thousand years prior to the seventeenth century, science had progressed little. Inquiry was largely discouraged, and experimentation almost nonexistent. As a result, science became regressive and discovery was ignored. Benjamin Farrington, a historian of science, characterized it this way: "Science had failed to become a real force in the life of society. Instead there had arisen a conception of science as a cycle of liberal studies for a privileged minority. Science ceased to be a means of transforming the conditions of life." In short, had this intellectual climate continued, humanity's future world would have been little more than a clone of its past.

Fortunately, these circumstances were not destined to last. By the seventeenth and eighteenth centuries, Western society was undergoing radical and favorable changes. And the changes that occurred gave rise to the notion that progress was a real force urging civilization forward. Surpluses of consumer goods were replacing substandard living conditions in most of Western Europe. Rigid class systems were giving way to social mobility. In nations like France and the United States, the lofty principles of democracy and popular sovereignty were being painted in broad, gilded strokes over the fading canvasses of monarchy and despotism.

But more significant than these social, economic, and political changes, the new age witnessed a rebirth of science. Centuries of scientific stagnation began crumbling before a spirit of scientific inquiry that spawned undreamed of technological advances. And it was the discoveries and inventions of scores of men and women that fueled these new technologies, dramatically increasing the ability of humankind to control nature—and, many believed, eventually to guide it.

It is a truism of science and technology that the results derived from observation and experimentation are not finalities. They are part of a process. Each discovery is but one piece in a continuum bridging past and present and heralding an extraordinary future. The heroic age of the Scientific Revolution was simply a start. It laid a foundation upon which succeeding generations of imaginative thinkers could build. It kindled the belief that progress is possible as long as there were gifted men and women who would respond to society's needs. When Antonie van Leeuwenhoek observed *Animalcules* (little animals) through his high-powered microscope in 1683, the discovery did not end there. Others followed who would call these "little animals" bacteria and, in time, recognize their role in the process of health and disease. Robert Koch, a German bacteriologist and winner of the Nobel prize in Physiology and Medicine, was one of these men. Koch firmly established that bacteria are responsible for causing infectious diseases. He identified, among others, the causative organisms of anthrax and tuberculosis. Alexander Fleming, another Nobel Laureate, progressed still further in the quest to understand and control bacteria. In 1928, Fleming discovered penicillin, the antibiotic wonder drug. Penicillin, and the generations of antibiotics that succeeded it, have done more to prevent premature death than any other discovery in the history of humankind. And as civilization hastens toward the twenty-first century, most agree that the conquest of van Leeuwenhoek's "little animals" will continue.

The *Encyclopedia of Discovery and Invention* examines those discoveries and inventions that have had a sweeping impact on life and thought in the modern world. Each book explores the ideas that led to the invention or discovery, and, more importantly, how the world changed and continues to change because of it. The series also highlights the people behind the achievements—the unique men and women whose singular genius and rich imagination have altered the lives of everyone. Enhanced by photographs and clearly explained technical drawings, these books are comprehensive examinations of the building blocks of human progress.

COMPUTERS

Mechanical Minds

COMPUTERS

Introduction

The Coming of the Information Revolution

In the late nineteenth and early twentieth centuries, people began building complicated machines to aid in making complex mathematical calculations. The designers quickly realized that such machines might do more than just add and subtract. They might also be used to *process*, or convert into simple form, large amounts of information. Eventually, these machines, which came to be known as *computers*, made possible a major technical revolution, the Information Revolution.

By the mid-1900s, the Information Revolution began to change modern society. Communications devices such as the telephone, radio, and television brought populations of millions of people closer together. Many large companies realized the need for other information devices to process vast amounts of information for and about the people making up these populations.

In 1948, mathematician Norbert Wiener published a book called *Cybernetics*, in which he predicted the coming

TIMELINE: COMPUTERS

1 ■ 500 B.C.
Abacus in use in China and Egypt.

2 ■ A.D. 1614
John Napier invents logarithms.

3 ■ 1632
William Oughtred invents the slide rule.

4 ■ 1644
Blaise Pascal develops first mechanical calculator.

5 ■ 1801
Joseph-Marie Jacquard uses punched-hole cards in a mechanical loom.

6 ■ 1833
Charles Babbage designs a primitive computer called the Difference Engine.

7 ■ 1890
Herman Hollerith uses punched-hole cards in an electromechanical machine to tabulate the U. S. census.

8 ■ 1924
Hollerith's Tabulating Machine Company changes its name to IBM.

9 ■ 1943
Howard Aiken builds the Mark I, an automatic calculating machine, for the U. S. Navy.

10 ■ 1946
Building of ENIAC, the first modern electric computer.

11 ■ 1948
Norbert Wiener's book *Cybernetics* predicts the coming of an advanced information age.

12 ■ 1951
Building of UNIVAC, first commercially successful computer.

13 ■ 1954
IBM develops FORTRAN, a scientific computer language.

of an age of advanced information machines. These devices, said Wiener, would bring a technical revolution as great or greater than the Industrial Revolution. "To live effectively," Wiener pointed out, "is to live with adequate information. Thus, communication and control belong to the essence of man's inner life, even as they belong to his life in society." Wiener and other scientists believed that such machines would eventually become complex enough to process information as well as the human mind. These scientists foretold the coming of the computer age.

Between 1960 and 1990, computers fulfilled Wiener's prediction by bringing about dramatic changes in human culture. Major developments and improvements came in such areas as communications, business and industry, space technology, education, health care, scientific research, and entertainment. Although computers still do not process information as well as the human brain, many experts predict that one day they will. This may bring about another technical revolution, one in which machines become capable of competing with human beings.

14 ■ 1958
Control Data Corporation introduces the first fully transistorized computer.

15 ■ 1964–65
IBM markets the System/360, the first commercial computer with silicon chips.

16 ■ 1968
Film *2001, A Space Odyssey* is released, featuring HAL, a fictional computer capable of independent thought.

17 ■ 1971
First hand-held electronic calculator introduced by Texas Instruments.

18 ■ 1976
Apple Computer, Inc. founded in a garage.

19 ■ 1977
Apple introduces the Apple II, the first mass-produced home computer.

20 ■ 1981
IBM markets the IBM PC personal computer.

21 ■ 1984
Apple introduces the "Macintosh," with advanced software and graphics.

22 ■ 1988
A computer worm penetrates and cripples thousands of computers in the U. S.

23 ■ 1989
Intel Corporation announces the 80860 chip, with the power of one million transistors.

24 ■ 1990
Robert Morris Jr. is tried and found guilty of spreading the 1988 computer worm.

■ ■ ■ ■ ■ ■ ■ ■ ■ CHAPTER 1

The Development of the Computer

There are two definitions for the word computer—one basic, the other advanced. The advanced definition, perhaps the more familiar, describes the modern computer. It is an electronic machine that performs high-speed mathematical calculations, stores, processes, and prints out information. One average modern computer can solve a complex math problem or examine and sort out a stack of legal documents more than one million times faster than a human being working alone. Modern computers have many functions and can be used in thousands of different ways.

But computers were not always so complex and versatile. They began as very simple devices with only one function. The first computers were devices for helping people count and do simple arithmetic. That is why they are called computers, because they were mainly used to compute.

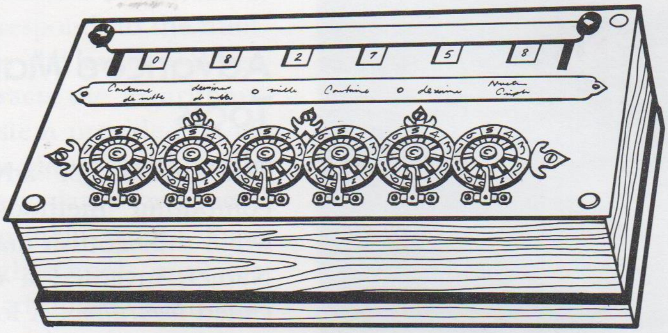
Early Computing Devices

The most primitive computers were people's fingers. If a primitive hunter wanted to tell a friend how many animals he killed, he held up the appropriate number of fingers. Three kills the first day plus five kills the second day added up to a total of eight kills, so the hunter showed eight fingers. Obviously, this system only worked well when the things being counted numbered ten or fewer. As civilization progressed, people's lives became more complex and they needed to compute and express larger numbers. So they developed more efficient ways of counting.

A common method of computing in many ancient societies was counting pebbles. The early Romans were familiar with this system; their Latin word for pebble is *calculus.* This led to the word calculate, which, like compute, means to count. Using pebbles as computers was much more efficient than using fingers. The pebbles could be painted different colors. A yellow pebble might represent the number 1. A blue one might stand for 10 and a green one for 100. Thus, by adding 1 green, 2 blues, and 5 yellows (125) to 2 greens, 3 blues, and 1 yellow (231) one could easily compute and express the number 356. Imagine how difficult it would have been for a hunter using his fingers to add those numbers.

Eventually, the pebble-computer became more advanced. Someone got tired of carrying around a large bag of pebbles. He or she substituted beads for the pebbles and decided to string the beads on wires. The wires were stretched between two sides of a wooden frame. Each wire held ten beads, which could slide back and forth. Each bead on the top wire stood for a 1. The beads on the second wire each stood for a 10, the ones on the third wire for a 100, and so on. Higher multiples of ten could be included simply by adding

THE FIRST MECHANICAL CALCULATOR



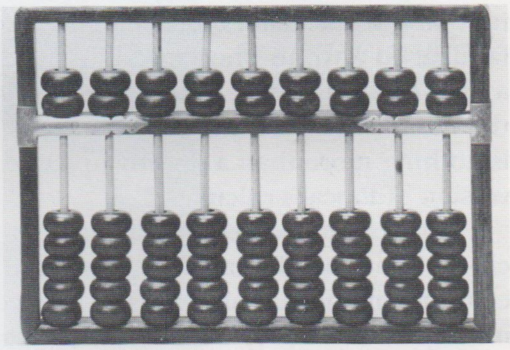
In 1642, Blaise Pascal invented this adding machine, which performed arithmetic when the linked dials were turned.

more wires. Now, a person could add 125 and 231 by pushing the appropriate beads from the left sides of the wires to the right. The number 356 was expressed as 3 beads on the third wire, 5 on the second, and 6 on the first. This calculating device was called an *abacus.*

No one knows for sure who invented the abacus, but it was widely used in China more than two thousand years ago. The early Japanese had a similar computing device called a *soroban.* A person worked these devices entirely by hand and could solve complex arithmetic problems very quickly. The Chinese and Japanese used these simple computers extensively up until the early 1950s.

Some people got tired of doing calculations by hand. They wanted to find a mechanical way to compute numbers that would be faster than using an abacus or writing the numbers out on paper. In 1642, Blaise Pascal, a French mathematician, built the first mechanical calculator. The device consisted of several wheels which interlocked like gears. Each wheel had numbers from 1 to 10 painted on it. When the first wheel turned through all ten numbers, the next wheel moved up one notch. Turning the first wheel around again moved the second wheel up another

Counting becomes easier with an abacus, its beads standing for ones, tens, and multiples of ten. This early adding machine was used widely in China more than two thousand years ago.



French mathematician Blaise Pascal built the first mechanical calculator, which used interlocking wheels.

notch. When the second wheel moved through all ten numbers, the third wheel moved up one notch. So, the first wheel stood for 1s, the second for 10s, the third for 100s, and so on. In a way, the wheels in Pascal's calculator corresponded to the wires in an abacus.

In 1671, a German mathematician named Gottfried Leibniz built a more complicated version of Pascal's calculator. Leibniz's model could compute higher numbers. But these early computers did not become popular. Even Leibniz's version could only solve simple math problems. And both devices were expensive to make. However, these mechanical calculators survived and are familiar to anyone who has ever driven a car. The odometer, which computes the number of miles the vehicle travels, is nothing more than a slightly updated version of Pascal's calculator.

Both Pascal and Leibniz had attempted to fill a need for more advanced counting methods. This need grew enormously in the 1600s because of major advances in science, especially in astronomy. Calculating the orbits of the heavenly bodies required solving extremely complicated math problems.

Advanced Mathematical Tools

The first major advance in modern computing methods came in 1614 when the Scottish mathematician, John Napier, invented a mathematical tool called *logarithms.* A logarithm is a number that stands for another number. Napier gave each number a logarithm and prepared tables in which he listed all the logarithms. For instance, in one standard table, the number 10 is represented by the logarithm 1, the number 100 by 2, and 1,000 by 3. If one wishes

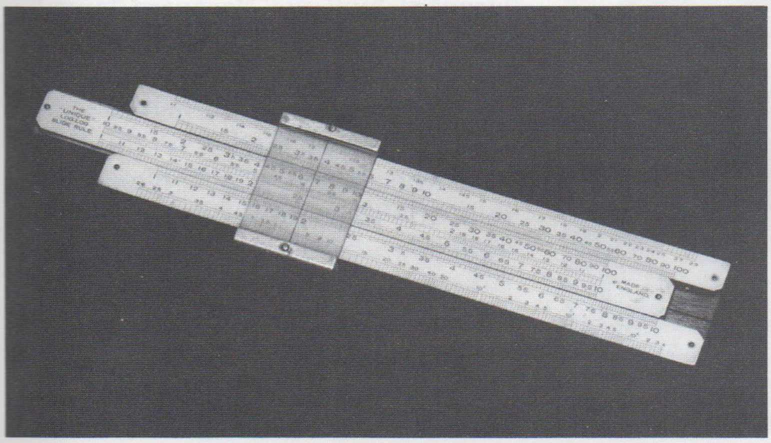
In 1671, German mathematician Gottfried Leibniz built a more complex version of Pascal's calculator. Still, the Leibniz calculator could solve only simple math problems.

to multiply 10 x 100, one looks up the logarithms for the numbers and adds them. Thus, 1 + 2 equals 3. When one looks up the logarithm 3 in the table, one sees that it corresponds to the number 1,000, which is the answer. When dividing, one subtracts the logarithms. This computing system provided an effective shortcut for doing math problems involving very large numbers. Math teachers routinely taught logarithms in most high schools until the mid-1970s. Some advanced math students still study logarithms.

The English mathematician, William Oughtred, found looking up logarithms tedious. In 1632, he invented a mechanical device designed to eliminate this step. He printed numbers on two wooden rulers. Then, he arranged the numbers in such a way that their positions on the rulers corresponded to their logarithms. The rulers were mounted so that they could slide by each other, so the device became known as a *slide rule.* When two numbers on a slide rule are lined up, the product of their multiplication can be read off a scale on one of the rulers. By lining up numbers on the device in various ways, a person can perform reasonably complicated math calculations. Scientists and most students used this simple but effective hand-computer well into the 1970s. A few schools still require their students to learn the use of a slide rule.

Scottish mathematician John Napier invented logarithms, a shortcut for doing math problems involving large numbers. Napier's invention marked the first major advance in modern computing methods.

But logarithms and slide rules are not always efficient and reliable. By the early 1800s, many scientists and mathematicians had become irritated that a slide rule could give only approximate

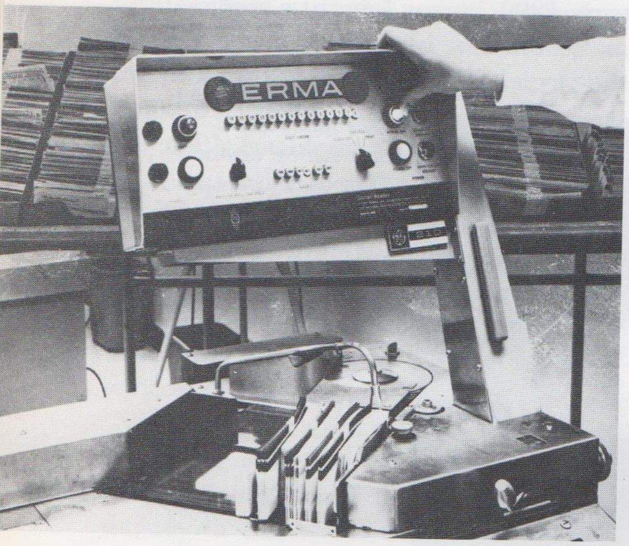


The slide rule, a mechanical device invented by an English mathematician in 1632, simplified the logarithms system of computing.

answers. Scientific disciplines such as astronomy, engineering, and chemistry were advancing steadily and demanded more precise measurements. Logarithm tables were difficult to prepare and often contained mistakes. People using such tables very often came up with the wrong answers.

The English mathematician, Charles Babbage, was particularly bothered by the lack of reliable mathematical computers. He decided to build a machine that could calculate logarithms automatically and not make mistakes. In the 1820s he designed a device with thousands of small metal rods, gears, and wheels, and called it the *Difference Engine.* But metalworkers at that time found it difficult to make parts small and precise enough for Babbage's machine. Also, building such a device was very expensive and Babbage sometimes had trouble raising the necessary money.

Early computers were clumsy by modern standards, but were faster and more efficient than performing tasks by hand.



After many years of attempting to build a working model of his automatic computer, Babbage decided to set aside the Difference Engine. He had what he thought was an even better idea. He would build a machine that could do more than calculate logarithms—one that could solve *any* sort of mathematical problem. The operator of the device would be able to move from one kind of problem to another, for instance, from addition to subtraction, by switching from one combination of rods and gears to another. This would instruct, or "program," the machine to perform a specific function. When the machine found the answer, the gears would stop turning and the device would hold the answer until the operator recorded it. In a sense, the machine would remember the answer for the operator, so the device would have a primitive "memory." Babbage also envisioned that his computer would be attached to a printing device so that the machine could print out the answers for the operator.

Babbage called his intended device the *Analytical Engine.* He planned to program the device to do various tasks with punched-hole cards. He borrowed the idea from a successful French inventor named Joseph-Marie Jacquard. In 1801, Jacquard built the "Jacquard loom," a device that could be programmed to weave different patterns. Before Jacquard, most looms consisted of individual threads, each carried by a thin metal rod. When a person pulled on specific rods, the rods carried the threads forward and worked them into the desired pattern. Jacquard designed a system in which rigid cards with holes punched in them stood in front of moving rods. Each card acted as a barrier to some of the rods, while allowing other rods to pass through the holes. The rods that got through formed the desired pattern automatically, without the aid of a person. Each card had different punched holes and produced a different pattern. Babbage realized that such a system could be used to program other types of machines and used the cards in his computer.

As he designed it on paper, Babbage's Analytical Engine had all the major features that modern computers have. It had the ability to perform advanced mathematical calculations and be programmed to do different tasks. It also had a primitive memory and a printing system. Therefore, if it had been successful, Babbage's machine would have been the first modern computer.

However, the device never worked properly. Many people thought Babbage was a dreamer and that his proposed computers were worthless ideas. After his death in 1871, most people forgot all about him and his great contribution to computer technology. But they did not forget about punched-hole cards.

The Need to Process Information

By the late 1800s, the need for reliable computing machines foreseen by Charles Babbage had expanded. In addition, the U.S. Government, and many large business firms, found a growing need to process vast amounts of information about citizens and consumers. The most notable example was the U.S. census. The census counted and collected information on every person in the country every ten years. Each individual information sheet had to be sorted and processed by hand. The 1880 census collected so much information that processing it took nearly the entire ten years leading up to the 1890 census.

The American inventor, Herman Hollerith, responded to the need for an information processor. He decided to combine Jacquard's and Babbage's idea of punched-hole cards with an electric power source. The result was a "census tabulating" device, the first electromechanical computing machine. Each census card had holes that represented bits of geographical or personal information about a citizen. For instance, a hole punched in a certain place in the "residence" column might indicate that the person lived in a city of more than 100,000 people. A particular hole in the "age" column showed that the person was forty-two years old. After a card was placed in a slot in the tabulator, a metal plate with hundreds of pins pressed against the card. The card stopped some of the pins but allowed others to pass through the holes. The pins that passed through picked up an electrical current which controlled dials on the face of the machine. All the operator had to do was put a card in the slot and read the information off the dials.

Several of Hollerith's tabulating computers were used in the 1890 census. Experts estimated that the new devices saved the taxpayers $650,000, a great deal of money at the time. The machines processed information for 62,622,250 people, the largest population in U.S. history up to that time, in only six weeks. Hollerith became so successful that he founded a company devoted to making different kinds of calculating machines. At first, he called the company the "Tabulating Machine Company." Later,

American inventor Herman Hollerith developed the first electromechanical information processor. His company is known today as International Business Machines Corporation, or IBM, the largest computer company in the world.

the company changed its name to "International Business Machines Corporation," or IBM. Eventually, IBM became the largest computer firm in the world.

A major advance over the punched-hole card came in the late 1920s, when the *vacuum tube* was first used in a computing machine. Inventors had already used such tubes in the first radios. A vacuum tube is a glass bulb, usually about two to four inches long, containing a strip of metal. The air is pumped out of the bulb, leaving the metal surrounded by empty space, or a vacuum. A person attaches one tube to each working part of a machine. When an electric current passes through the machine, some of the tubes allow the current to reach the parts they are connected to. These parts then operate normally. Other vacuum tubes do not allow the current to reach their parts until those parts are needed. Therefore, the tubes act like switches to turn the current on and off for specific parts. In a machine with many parts and tubes, some tubes may be switching parts on while other tubes are switching parts off. Thus, a series of vacuum tubes can control the parts of a machine in a selective way, just as a punched-hole card can. The advantage of the tube over the card is speed. Inserting and removing a card takes several seconds, while an electric switch works in a fraction of a second.

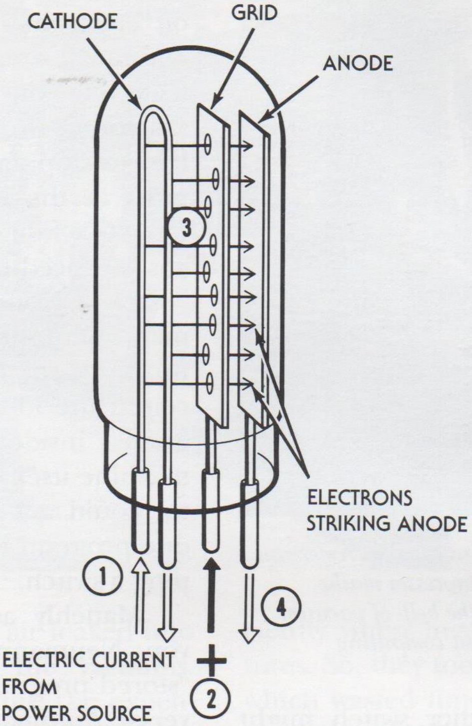
In 1930, the American engineer, Vannevar Bush, used vacuum tubes in a large, complicated computing machine. Designed to solve any math problem, the device, called a *differential analyzer,* was a modern version of Babbage's computing device. Bush's machine processed mathematical information but was not designed to handle more general data, as Hollerith's census tabulator was.

A more advanced version of Bush's computer was designed by an American mathematician, Howard Aiken, in 1943. Aiken received money from the government and from IBM to build a device which would help the U.S. Navy. This first military computer was called the Mark I. It was a great aid to naval gunners, who had to solve complicated math problems in order to hit moving targets. But, like Bush's device, the Mark I was designed for one specific job. No one, as yet, had built an all-purpose electronic machine that could compute numbers *and* process general information.

The Prototypes of Modern Computers

Two American engineers, John Mauchly and John Eckert, recognized the need

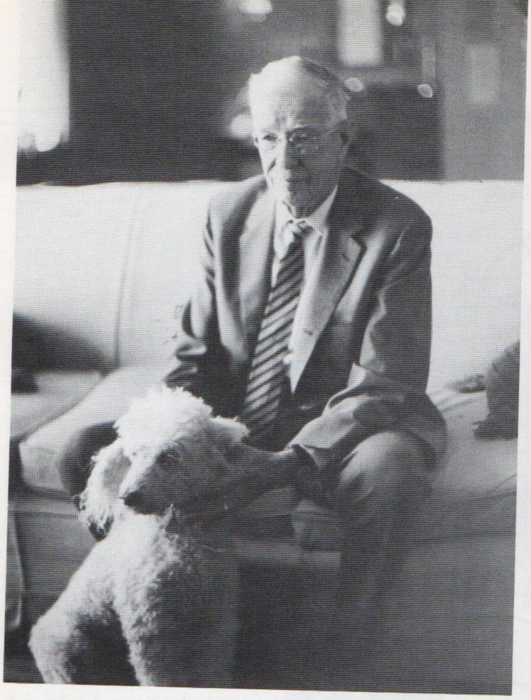
THE VACUUM TUBE



The earliest electronic computers used thousands of vacuum tubes as switches, which convey information by turning electric currents on and off. Each airtight tube has three key parts, a cathode, a grid, and an anode. The cathode is a thin electric wire, the grid is a thin metal screen, and the anode is a thin metal strip. When connected to a power source, an electric current runs through the cathode (1). To turn the switch on, the grid receives a positive electric charge (2). This attracts the negatively charged electrons from the cathode. The electrons pass through the grid to the anode (3). This completes an electric circuit, which means the switch is "on" (4). When the grid is not positively charged, it does not attract electrons from the cathode. This breaks the circuit, or turns the switch "off."

for a powerful, all-purpose computer. In 1946, they introduced the "Electronic Numerical Integrator and Calculator," or ENIAC. This was the first modern electronic computer. ENIAC was huge. It weighed thirty tons, filled an area of more than fifteen thousand square feet and had some nineteen thousand vacuum tubes. Though cumbersome, ENIAC constituted a major advance in technology. For the first time in history, a machine could calculate numbers and process information a great deal faster than a person could. ENIAC operated at least one thousand times faster than a person using an abacus.

ENIAC's vacuum tubes acted like small switches. Each switch stood for a certain number or piece of information. For instance, one switch might represent



The differential analyzer, invented by American engineer Vannevar Bush, processes mathematical information with the help of vacuum tubes in a large, complicated computing machine.

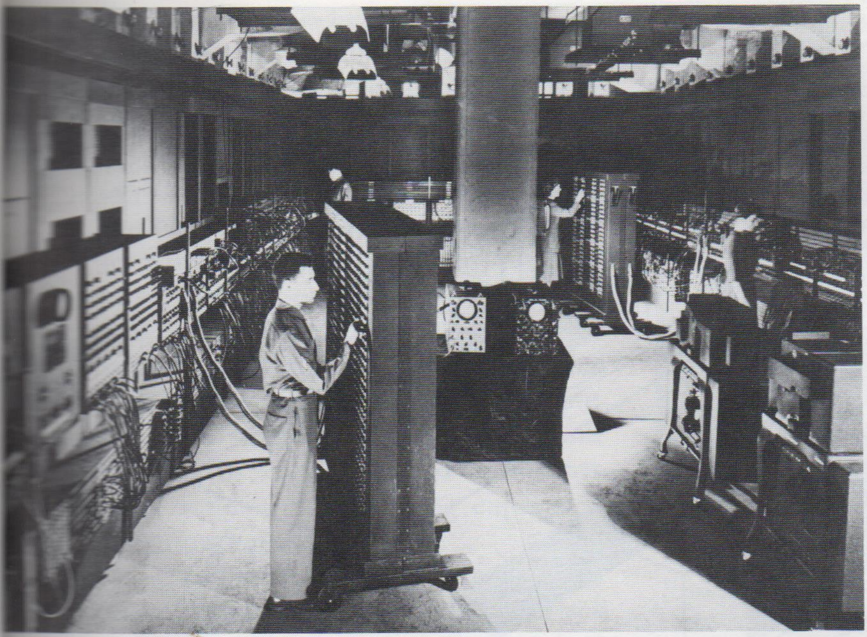
the number 3. Another switch might represent a multiple of 10. If an operator programmed the computer to solve the problem 3 x 10, both switches opened and the machine registered the answer—30. Of course, with tens of thousands of tubes and other parts, the computer could quickly process much more complicated information than this. In fact, ENIAC could perform five thousand additions of ten-digit numbers in a single second. Thus, it became a revolutionary aid to scientists, who now began measuring computer functions in *milliseconds.* A millisecond is one thousandth (1/1,000) of a second. ENIAC also had a memory in which it stored individual pieces of information and a printing unit that printed out information on command.

Some scientists, government officials, and business leaders saw the new device as only the beginning of a revolution in machine "intelligence." Many people began talking about the coming of "electronic brains." But ENIAC had one major drawback. In order to switch from one type of program, or set of instructions, to another, the operators had to stop and rewire certain control units in the machine. This was a tedious as well as time-consuming and costly procedure.

The Hungarian-American mathematician, John von Neumann, solved this problem in the late 1940s. He conceived the idea of storing various programs inside the memory of the machine itself. Now, a computer operator could tell the machine to go from one program to another simply by flipping a switch.

Mauchly and Eckert incorporated von Neumann's ideas into the first "stored program" computer—the "Universal Automatic Computer," or UNIVAC I. They introduced the machine in 1951 and it became the first computer to be sold commercially. Large business firms, government agencies, and universities bought models of the UNIVAC. Each group used the computer to cut down the time and costs of processing huge amounts of information. Science labs used the device to solve complex math problems and the U.S. Census Bureau used it twenty-four hours a day for twelve years. Finally, in 1963, more advanced computers replaced UNIVAC. One model of the machine can be seen in the Smithsonian Institution in Washington, D.C.

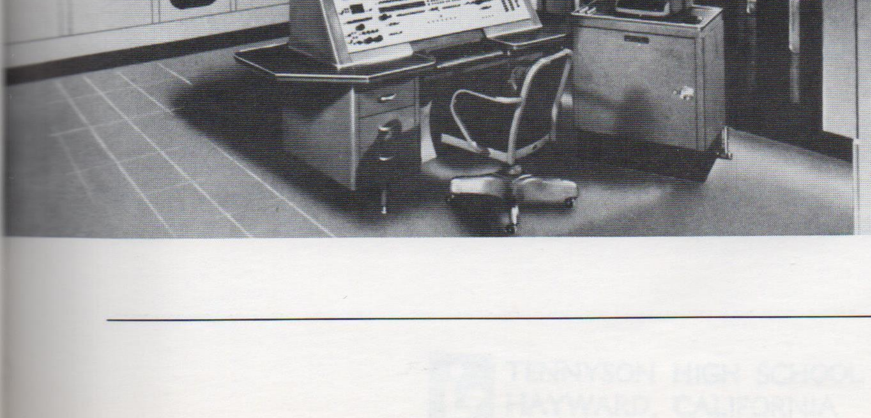
ENIAC and UNIVAC each used thousands of vacuum tubes. Even as engineers built these computers, they recognized that the tubes had many problems. In the first place, they were made of glass and easily broken. Also,



ENIAC, or Electronic Numerical Integrator and Calculator, was the first modern electronic computer. It could calculate numbers and process information a thousand times faster than a person using an abacus.

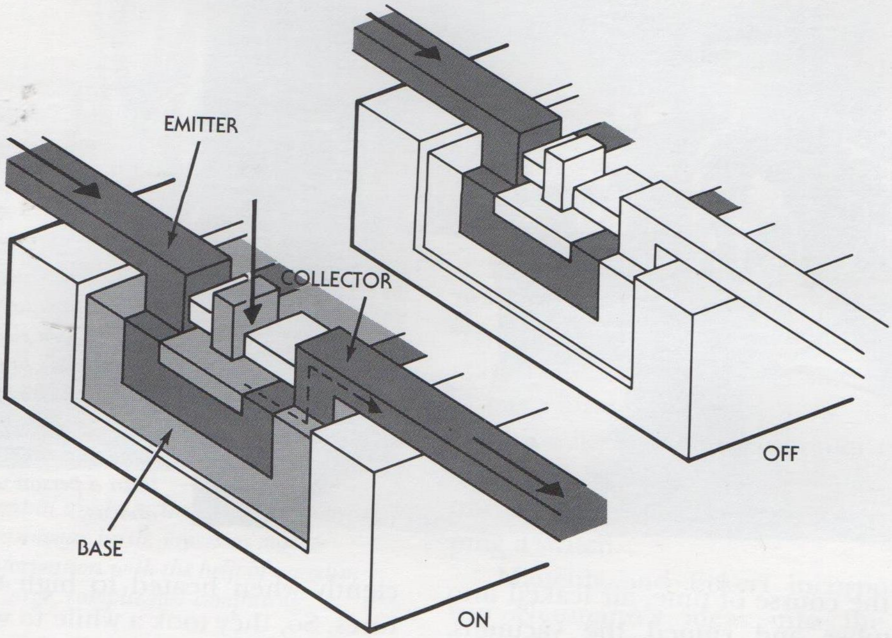
over the course of time, air leaked into the tubes and ruined the vacuums. Because of these problems, the expensive tubes had to be replaced often. In addition, the tubes took up a great deal of space, which meant the computer itself had to be large in order to hold them all.

Still another problem with vacuum tubes was that they only worked efficiently when heated to high temperatures. So, they took a while to warm up, which wasted time. The hot tubes also needed a lot of energy to operate. ENIAC, located in Philadelphia, used 150,000 watts of electricity each day. When operators turned it on at night, it drained enough power to momentarily dim lights over most of the city. And all the heat generated by the tubes ne-



UNIVAC I, the first stored-program computer, also was the first computer to be sold commercially. More advanced computers replaced UNIVAC in 1963.

THE TRANSISTOR



The invention of the transistor in 1948 revolutionized the computer. Transistors were used in place of vacuum tubes as the switches that convey "on" or "off" signals. They were much smaller, cheaper to make, and more reliable than vacuum tubes, but they worked on the same principle. A transistor signals "on" when an electric circuit is completed. This occurs when the base of the transistor is given a positive charge, allowing a current of electricity to pass from the emitter to the collector. When the positive charge is removed, the circuit is broken, and the computer interprets it as an "off" signal.

cessitated that such computers be placed in special air-conditioned rooms. These numerous problems and extra costs associated with vacuum tubes gave scientists a strong incentive to find a more reliable replacement.

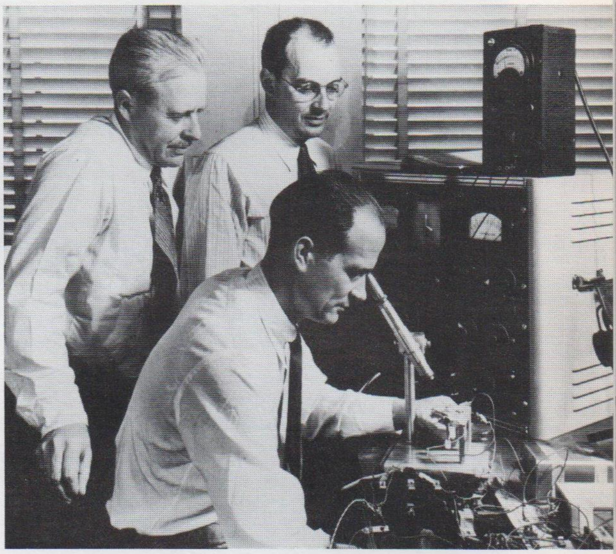
Computer Generations

The next great turning point in the evolution of modern computers came in 1948. Three American scientists invented a device to replace the vacuum tube. Working at the Bell Labs in New Jersey, William Shockley, Walter Brattain, and John Bardeen experimented with silicon, an element found in ordinary rocks. The men placed pieces of silicon inside tiny metal containers in such a way that an electric current passed through them. The invention was called a *transistor.* The electricity in a transistor flowed through a solid material rather than through empty space, as in a vacuum tube. Therefore, transistors came to be known as "solid state" devices.

[redacted]

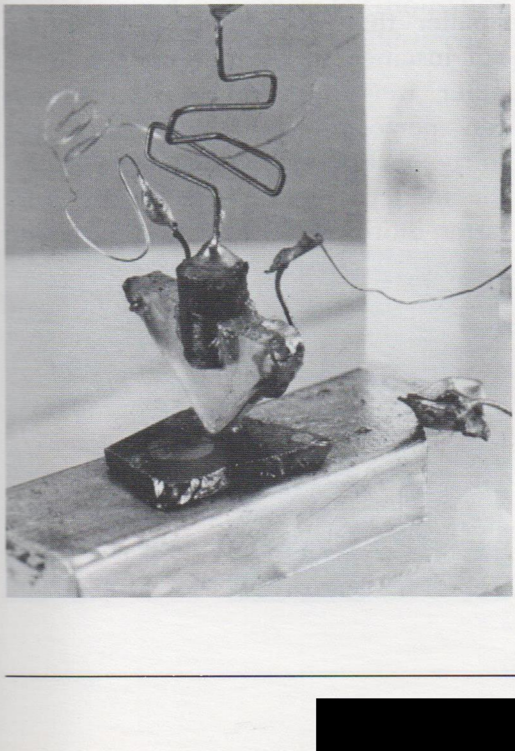
The inventors found that a transistor could be used to start and stop an electric current just like a vacuum tube could. But transistors had many advantages over tubes. Because transistors were solid, they rarely broke and could not leak. Also, transistors were cheaper to make than tubes and did not have to warm up before use. This saved time and energy. The key advantage to transistors was their size. They were much smaller than vacuum tubes, so computers with transistors could be made smaller. In fact, the word "transistorized" soon became a slang expression meaning "miniaturized."

Transistors also performed faster than tubes. This gave transistorized computers higher *computation speeds.* A computer's computation speed is the number of separate functions it can perform in a second. Computers using tubes, such as ENIAC and UNIVAC, had computation speeds of one-thousand to five-thousand additions per second. These devices became known as *first generation* computers. Computers using transistors, like the IBM model 7090, had computation speeds as high as 500,000 additions per second, a dramatic improvement over previous devices. Transistorized computers became known as *second generation* computers. Scientists now began measuring computer functions in *microseconds.* A microsecond is one-millionth (1/1,000,000) of a second.



Experiments with an element found in ordinary rocks, called silicon, led to the invention of the transistor by scientists William Shockley, John Bardeen and Walter Brattain.

A turning point in the development of computers came with the invention of the transistor in 1948. Shown here is an early transistor.



Although transistors first appeared in 1948, several years passed before they could be used in large computers. Most transistorized computers were built and sold between 1958 and 1964. During this same period, computer engineers tried to find ways to further miniaturize computer parts. Their largest motivation came from the space race between the United States and Soviet Union. After

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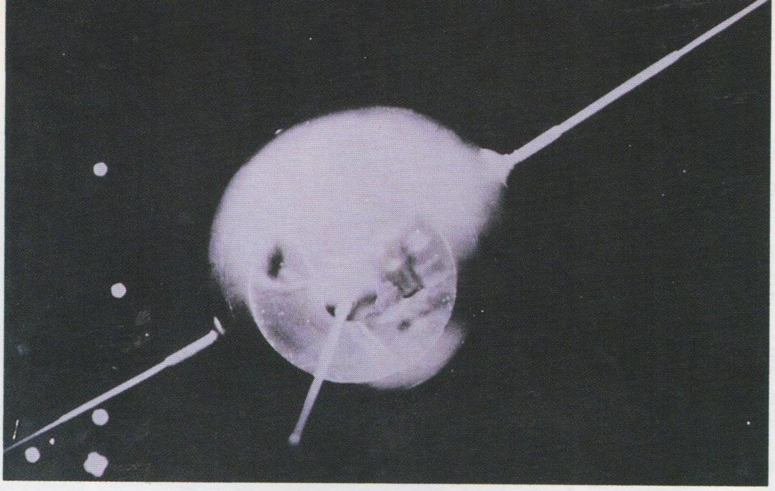
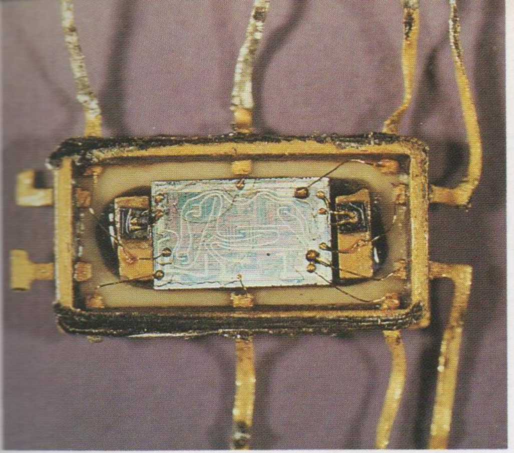

The Sputnik launch in 1957 fueled the space race with the United States and hastened the search for ways to further miniaturize computer parts.

the Soviet Union launched Sputnik 1, the first artificial satellite, in 1957, the U.S. government became determined to surpass the Soviets in space science. Space experts needed high-speed computers aboard satellites to handle complex problems of guidance and translate radio signals sent from Earth. American scientists worked hard to make computers smaller and lighter so that the devices would not weigh down the rockets that launched the satellites.

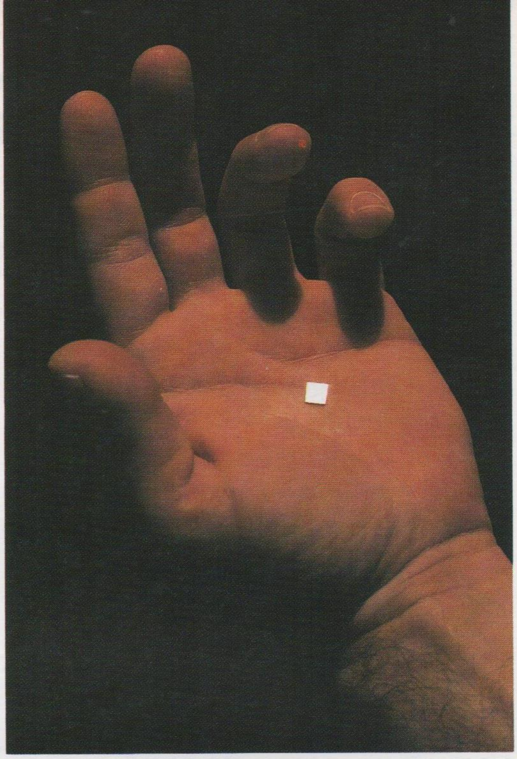
Transistors made computers smaller but not small enough for satellites. The trouble was that there were many other parts besides the transistors in a computer. The transistors acted like switches, turning the electric current on and off. Each transistor was connected to several parts—wires, connectors and so on. Together, a transistor and its adjacent parts made up a *circuit,* a path taken by the electric current as it moved through the machine. Although transistors were small, circuits were still relatively large.

Beginning in the late 1950s, scientists cut pieces of pure silicon into tiny flat wafers. The researchers used a microscope to watch as they used powerful acids to carve patterns in the silicon wafers. These patterns represented all the parts, including transistors and wires, that made up a normal circuit. Electricity flowed through the patterns on the wafers just as it had through transistorized circuits. Because all the parts of a circuit were unified, or integrated, on one piece of silicon, the pieces became known as *integrated circuits.* Scientists also called the individual pieces *chips.* When researchers later made chips even smaller, the wafers became known as *microchips.*

A microchip is thousands of times smaller than a vacuum tube. Also, the chip can perform more functions than a vacuum tube, which merely acts as a switch to turn an electric current on and off. Therefore, computers using chips can be made thousands of times smaller than computers using tubes. For instance, an average modern computer weighing only a few pounds can perform all the functions the thirty-ton ENIAC could. What is more, the modern version can do the work faster, more efficiently and at a fraction of the cost. Computers utilizing chips are known as *third generation* computers. They have computation speeds of tens of millions of additions per second. Scientists now measure computer functions in *nanoseconds.* A nanosecond is one-billionth (1/1,000,000,000) of a second. The first major commercial computers using chips were the IBM/360 computers that hit the market in 1964.



Integrated circuits were developed in the late 1950s. Unlike transistorized circuits, all the parts of an integrated circuit are unified on one piece of silicon.

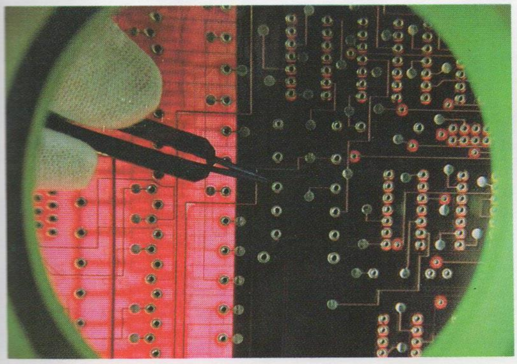


A tiny silicon wafer microchip is thousands of times smaller than a vacuum tube and can perform more functions. Computers using microchips can be made much smaller than computers using tubes.

Microchip technology quickly led to smaller, hand-held computers designed to aid in conventional math computations. These inexpensive "pocket calculators" sold by the millions beginning in the early 1970s. Every student could now afford to have his or her own portable computing device. As a consequence, more primitive computers, like logarithms and slide rules, rapidly became obsolete.

Supported by continually improving technology, computer engineers have designed computers for thousands of specialized purposes. Modern computers perform tasks as simple as keeping track of the family bills and as complex as coordinating telephone networks connecting millions of homes. Computers can listen, talk, draw pictures, fly airplanes, fire laser beams, and find and correct their own errors. Some computers can even design other computers. These complex machines affect nearly every aspect of people's personal and professional lives. Computers have become essential tools in the fields of science, communications, business, and entertainment.

A computer circuit board, seen under a magnifier, provides a glimpse into changing computer technology.



The computer has come a long way since the time of primitive hunters. In those days, it recorded a few facts about the world on people's fingers. Now, it brings a world of information to people's fingertips.

■ ■ ■ ■ ■ ■ ■ ■ ■ ■ CHAPTER 2

How a Modern Computer Works

Modern third-generation computer systems are made up of many individual parts, or components. Each component has its own function. Computer experts separate the different types of computer components into two basic categories—*hardware* and *software.*

Computer Hardware

Generally speaking, the hardware of a computer system consists of its physical, or machine, elements. In the case of very large computers, like some used in scientific research, these elements might be placed far apart. They are then connected to one another by wires so that they still function as a single unit. Smaller computers, like the ones people buy for use at home, have all their hardware elements packed conveniently in two or three plastic containers. For instance, a common home computer system consists of a keyboard, a monitor screen, and a control unit, called a desktop system.

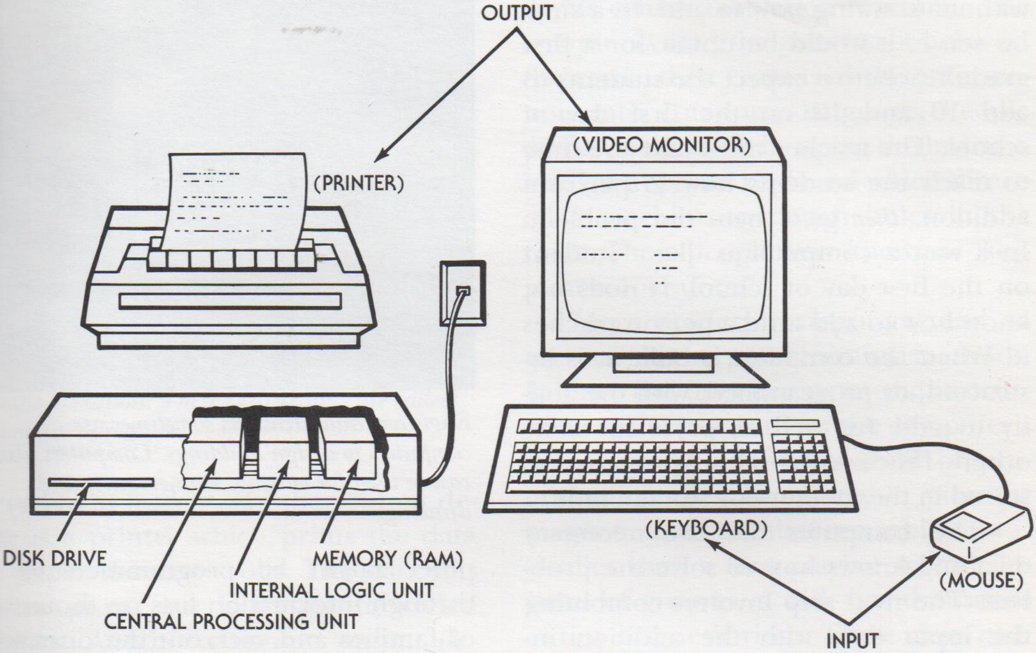
Regardless of whether computers are large or small, they all contain five basic elements, or units. These are the *input, memory* (or storage), *control, processing* (or logic), and *output* units. In the desktop computer described above, the keyboard is the input unit and the monitor screen is the output unit. The memory, control, and processing units are all packed into the control component.

The input unit of a computer receives information, or data, from outside the computer system. The unit then changes the data into a special language which the computer has been designed to recognize. As a simple example, suppose a person wants to find the answer to the problem 10 + 10. The person types the problem on the computer's keyboard. The computer's other units do not recognize the symbols 10 or +, so the input unit changes each symbol to its equivalent in an electronic computer language.

Now that the data has been fed into the machine through the input unit, the computer is ready to solve the prob-

A young boy learns to use a computer, first by learning the functions of the keys and then by doing exercises that appear on the screen.

BASIC PARTS OF A COMPUTER



Computers today use a wide variety of hardware, software, and accessories. But all have these six basic components:

(1) Input: A way to communicate with the computer, such as a keyboard or a mouse.

(2) Central Processing Unit (CPU): The brains of the computer. This unit directs the computer's activities. Every instruction given by the operator must first pass through the CPU before it can be carried out.

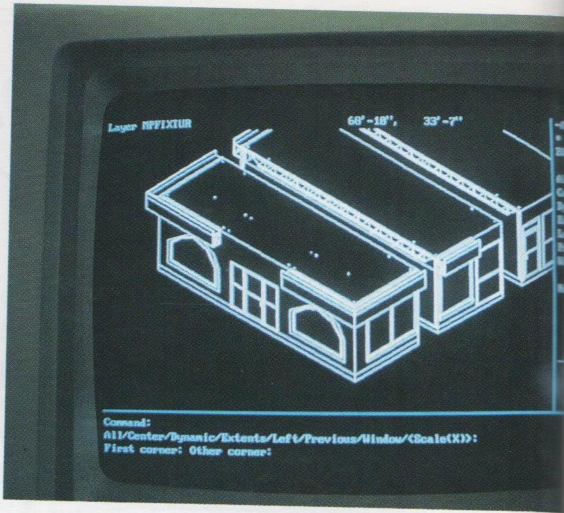
(3) Memory: A unit to hold programs and information while the operator works with them. This memory, called RAM (for random access memory) in the personal computer, can be changed or added to, but each time the power is turned off, RAM is wiped clean.

(4) Internal Logic Unit: This is a form of memory that cannot be altered. It contains the basic information the computer needs in order to function. In a personal computer, this unit is called ROM, or "read only memory."

(5) Output: This is usually a video monitor or a printer that allows the operator to receive information from the computer.

(6) Communication: A way for the computer to send, receive, and save programs or data. On the personal computer, this is usually a disk drive, which stores or reads information on disks.

lem. It is ready because it already understands *how* to solve it. No one expects a computer to solve such a problem without knowing how to add. In a similar sense, it would be unfair for a first grade teacher to expect the students to add 10 and 10 on the first day of school. The teacher must take the time to teach the students how to perform addition, *then* give them the problem. In a way, a computer is like a student on the first day of school. It does not know how to add until a person teaches it. When the computer is built, it is instructed, or programmed, with the ability to add (as well as perform many other functions). This program is stored in the memory or storage unit.



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Command:
All/Center/Dynamic/Extents/Left/Previous/Window/<Scale(X)>:
First corner: Other corner:
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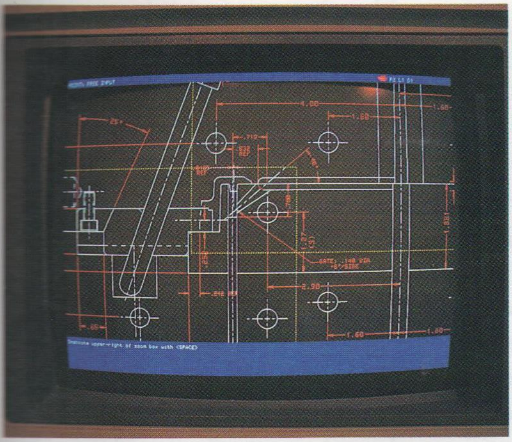
Engineers and architects sometimes use computers to design buildings. Computers also can be used for writing, mathematics, and drawing.

The computer has the necessary data and knows how to solve the problem. The next step involves combining the input data with the addition instructions from the memory. This step is accomplished by the control unit. All of a computer's inside functions are guided by the control unit. This unit examines the input data, sees that it consists of two numbers to be added and selects the addition function from the memory.

Finally, the computer solves the problem. The control unit orders the processing or logic unit to perform the actual addition of the two numbers. The processing unit is sometimes referred to as the "arithmetic" unit because it carries out basic operations associated with simple mathematics. These operations include addition, subtraction, multiplication, and division. The processing unit can also compare one piece of information to another. This gives the computer the ability to tell if separate groups of data are the same or different. For example, a computer might be programmed to go through information lists on thousands of families and pick out the ones with children. The processing unit "understands" that the families with children belong to a specific group and separates them from others on the list.

After the processing unit has added 10 + 10 and has found the answer to be 20, there is still one more step to be performed. The answer is still in the form of special symbols which are part of the computer's electronic language. The output unit changes the computer language symbols back into the familiar numerals 2 and 0, which compose the number 20.

Another job of the output unit is to display the answer so that the computer operator can read it. This can be done in a number of different ways. One common output device is a monitor screen, or Video Display Terminal (VDT), on which the output data is displayed. Because it can be read off the screen, this information is often re-



Software tells the computer how to perform a specific operation. These instructions are called a computer program.

ferred to as *readout.* Another output device is a printer which prints the data on paper sheets or rolls. The data this device prints out is frequently called *printout.* Another common output device records data on magnetic tape, which can be played back as often as the operator desires.

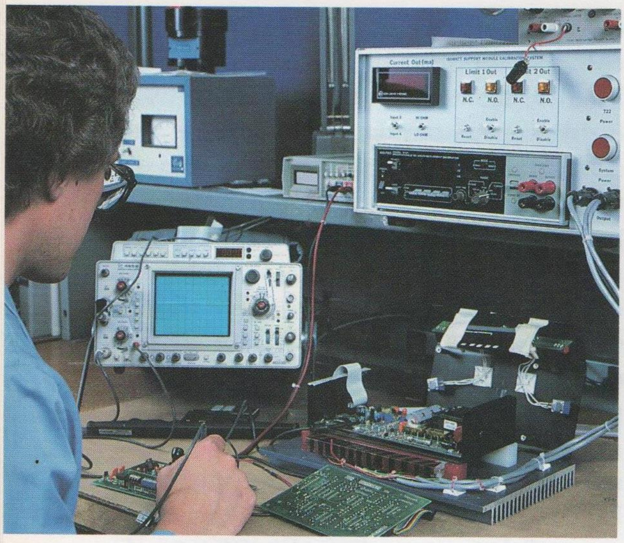
Computer Software

The term software generally refers to any extra items involved in a computer system that are not part of the basic hardware. The most common computer software consists of instructions that are designed to show a computer how to perform a specific operation. These instructions are called a *computer program.* Software usually also consists of a set of instructions for the computer operator. Printed on paper, these tell the operator what a particular program is about and how to feed it into the computer's input unit.

The program can be fed into the input unit in several ways. Older computers, like the ENIAC, UNIVAC and many computers of the 1960s, used punched-hole cards like the ones Hollerith used in his census tabulation machine. The computers read the patterns of holes on the cards, then converted this information into computer language. People prepared the cards by typing the instructions on a special keyboard which directed a machine to punch holes in the cards. These people were known as "keypunch operators."

More modern computers tend to use one of two programming methods. In one, the operator types the instructions of the program on the computer's keyboard. The other method of programming uses a *disk,* a thin piece of magnetic material that resembles but is smaller than a long-playing record. Instead of grooves, a disk has thousands of tiny magnetic rings. These rings contain all of the information of the program. Such disks are also used to store information after it has been processed by the computer.

Thin pieces of magnetic material, called disks, are used for programming computers and storing information after it has been processed by the computer.



A technician tests computer circuitry and equipment.

Computers are referred to as "programmable devices" because they can be programmed to perform many tasks. Two types of programs are used by the average computer. One is the stored program that forms the basic part of the machine's memory unit. This is the program built into the machine, which remains fixed, or unchanged, no matter what job the computer is doing. For this reason, people do not usually think of a computer's basic program as software. But the basic program is essential because it forms the foundation on which the other software programs operate.

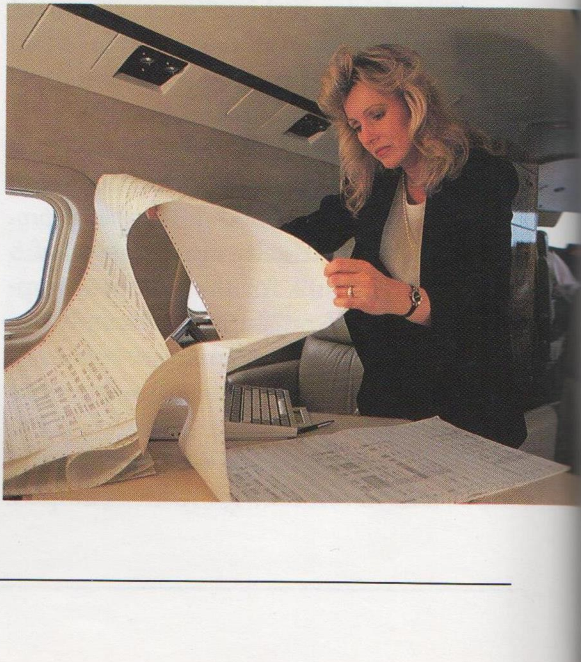
The basic program of a computer usually consists of a set of extremely simple instructions. These generally include such directions as:

- examine data from input
- transfer data from memory to output
- move data from one part of memory to another
- add, subtract, multiply, or divide numbers
- change a piece of information as instructed
- stop

Even the most advanced computers have no more than a few hundred such basic instructions. The average desktop computer has only a few dozen. This seems to imply that a computer can only do simple things. But exactly the opposite is true. A software program utilizes the computer's few basic instructions in a complicated way. Such a program might call for the computer to add, multiply, transfer, move, or change data hundreds or even thousands of times. Each separate command instructs the machine to perform a specific function.

The key to making such a complicated set of commands work efficiently is speed. As explained earlier, modern computers have computation speeds of millions of functions per second. Each

Computer printouts provide the same information on paper that is stored in computer memory.



command consists of one or no more than a few additions. Even if a certain software program requires five thousand separate additions, an average computer can complete that program in a tiny fraction of a second. Part of this time is devoted to translating the software language into the language of the machine itself.

Computer Languages

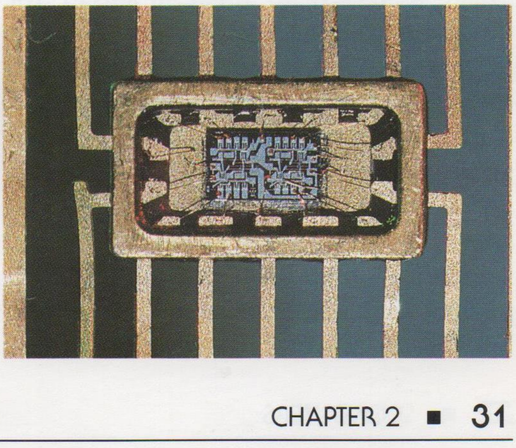
There are two basic types of computer languages: *low-level* languages and *high-level* languages. Low-level computer languages are also called machine languages. A machine language is the particular set of electronic symbols recognized by the internal parts of a computer. The form a machine language takes is dictated by the way a computer works. Vacuum tubes, transistors, and chips all work on the principle of starting and stopping an electronic current. Thus, there are only two possibilities: the current is either on or it is off. The simplest way to represent these possibilities is by assigning each "off-current" a 0 and each "on-current" a 1. Using this system, computer designers found that the most logical method to program the internal parts of a computer was to express numbers and information as different combinations of 1 and 0.

Numbers expressed as different combinations of 1 and 0 are known as the *binary numbers*. In the binary system, the number 1 is expressed as 0001, the number 2 as 0010, 5 as 0101 and 15 as 1111. Binary numbers made up the first and most common low-level, or machine, language. In a computer, each 1 or 0 is called a *bit*. A *byte* is eight bits which are combined to form numbers, letters, and symbols. When computer experts talk about how much information can be stored in a computer, they refer to the number of bytes the machine can hold. One thousand bytes make up a *kilobyte* (K) and one million bytes make up a *megabyte* (M). Some modern computers can hold more than four megabytes of information on a single tiny silicon chip.

Early computer programmers also used low-level machine languages in software programs. The people translat-

People use computers in their everyday lives for tasks such as keeping track of their finances.

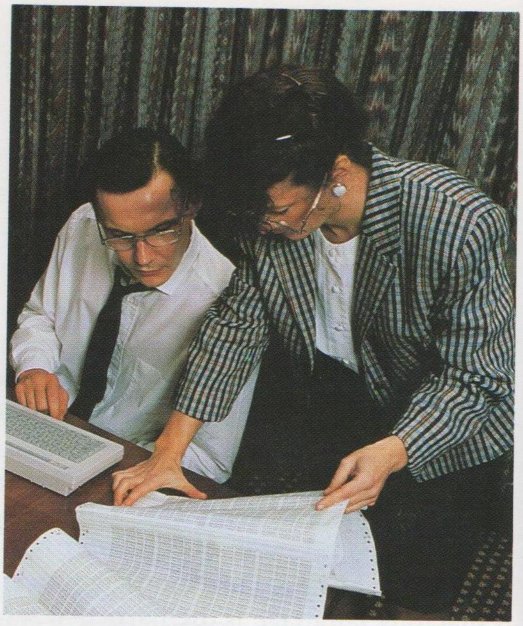
One tiny silicon chip can hold thousands or millions of pieces of information.



ed their instructions into binary numbers made up of 1s and 0s and fed them into their computers. But, writing out long lines of 1s and 0s is time-consuming. Programmers frequently made mistakes that required hours to locate and correct.

Such drawbacks led computer experts to develop more understandable computer languages for software programs, called high-level languages. Thus, every modern computer uses two different languages. One is high-level and used by people to deal with input and output data. The other is low-level and used by the internal components of the computer to relay and process information. First, a computer programmer writes a program in a high-level language and enters it into a computer. Then, the program is translated into a low-level machine language. Later, the machine reconverts the information into the high-level language for readout or printout.

The most widely used high-level language in the world is known as COBOL, which stands for Common Business Oriented Language. COBOL looks a lot like English because it has many familiar English words, such as "multiply," "new," "write," "output," and so on. However, COBOL is not English. Computer experts designed the language that way to make it easier for people to develop and read programs. As its name implies, COBOL is particularly useful for doing business-related tasks. Examples are compiling categories of taxpayers for the government and figuring out inventory for a company.

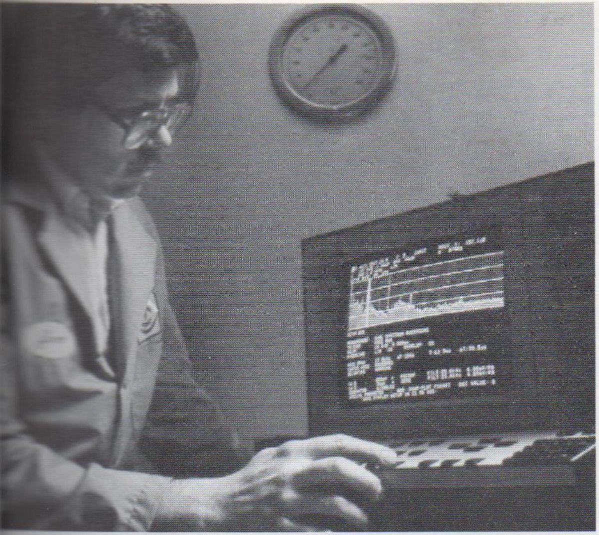


Computers are essential tools in many modern businesses.

Other high-level computer languages are useful in various other areas. FORTRAN (Formula Translation) works well for scientists and engineers. ALGOL (Algorithmic Language) is favored by mathematicians. BASIC (Beginners' All-purpose Symbolic Instruction Code) is a simple high-level language designed for easy learning. Examples of terms in the BASIC language are: + (add), - (subtract), * (multiply), / (divide), end (stop running program). Because BASIC can be learned quickly, people who know very little about computers can use it to write their own programs.

Computer Performance

Primitive computers, like an abacus or a table of logarithms, have something in common with modern computers. All are tools used by human beings to solve problems and process information. Of course, modern electronic



Many companies use high-technology computers to test products.

computers are far more complicated than any of the computing tools that preceded them. In fact, modern computers are the most complex tools ever invented. As long as they are designed, built, and programmed properly, they will perform thousands of tasks quickly and accurately.

Yet, even a very efficient tool is not infallible. Like other tools, computers can make mistakes. There are two types of errors associated with tool use. One is a physical flaw in the tool itself. The other is a mistake made by the person using the tool. For instance, consider an ax. As long as the ax is sharp and the woodchopper swings it properly, the tool performs admirably. But if the ax gets dull or the woodchopper swings too low, the tool performs poorly.

Similarly, a computer can perform poorly because of a physical flaw or a person's mistake. A component can become damaged or a part can wear out. A sudden surge of electricity might erase some important stored information. But these kinds of problems are rare in computers. By far the most common cause of computer mistakes is human, or programming, error. A computer can only do what it is told to do. If the person programming a computer makes a mistake, the computer will also make mistakes. Such errors can be merely irritating, as when a computerized utility bill wrongly charges a customer five times more than is actually due. Other computer errors can be dangerous. For example, on at least three occasions, a military computer issued a false warning and ordered U.S. bombers to go to war. Luckily, in each case, the mistake was discovered in time and no one was hurt.

People cause such computer errors by feeding the wrong information into a computer. Computer programmers have a saying: "garbage in, garbage out." This means that if one feeds faulty data into a computer, one will most certainly get the wrong answers. For this reason, computer programmers strive to be as accurate as possible. They know that it is up to them to ensure that the modern super tool known as the computer will continue to benefit humanity.

■ ■ ■ ■ ■ ■ ■ ■ ■ CHAPTER 3

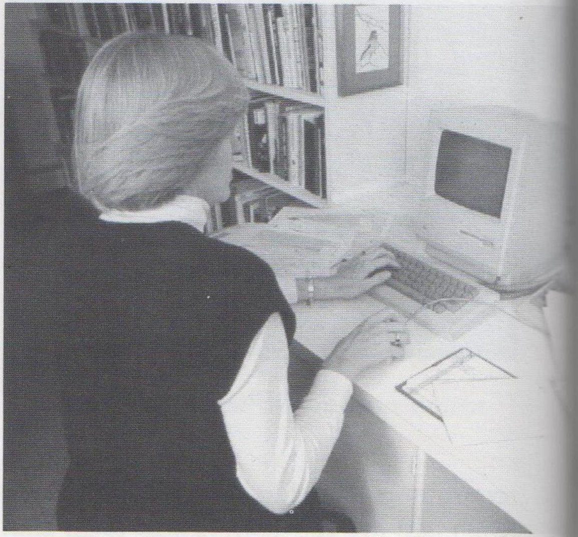
Computers in Business and Industry

In the late 1950s and early 1960s, the American business world began to discover the computer. Some companies immediately saw the great potential of the new device for speeding up the processing of information. Business leaders recognized that their employees spent 20 percent of their time generating paperwork. Such work included figuring the company payroll, billing customers, compiling statistics, doing inventories, and preparing reports and taxes. Since computers could complete all these tasks very rapidly, the devices could greatly reduce the amount of time a company spent on paperwork. Many companies realized substantial financial savings, usually after using computers for only a few months. Thus, although computers were relatively expensive to purchase, a company could make back its initial investment very quickly.

Thousands of American businesses, lured by the promise of saving time and money, invested in computers. Between 1960 and 1990, virtually every large business in the U.S., as well as many businesses in foreign countries, became computerized. In offices and factories, in banks and supermarkets, people restructured their jobs and their ways of doing business around the computer.

Office Computers

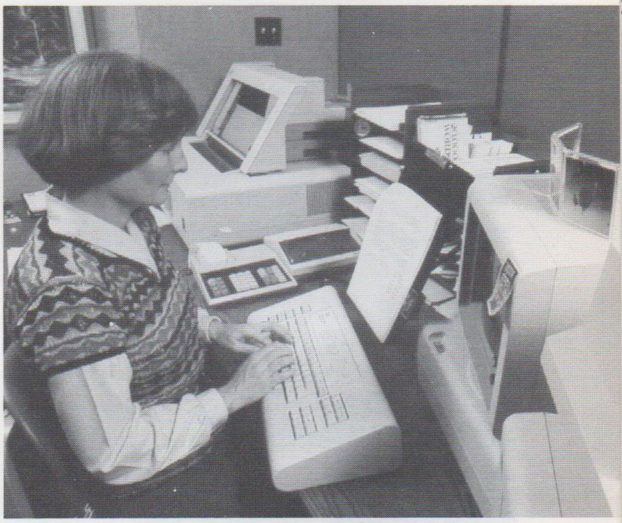
For most businesses, the office is the nerve center in which the processing of company information occurs. Therefore, many businesses installed computers in their offices. The secretary's traditional typewriter gave way to a computer keyboard and monitor screen. Often, office computer systems are specialized according to the kind of work a particular company does.



American business began discovering computers in the late 1950s and early 1960s. Computers took a little longer to catch on as a household tool.

For instance, credit card companies program large computers with the names, addresses, and financial histories of each of their customers. Such a computer is connected to many individual outlets, called *terminals.* When a customer phones in, an operator types the person's name on the terminal's keyboard. In seconds, all information relating to that customer is displayed on the monitor screen. This enables the operator to immediately deal with the customer's request or problem. Any changes or additions to the customer's file are automatically stored in the computer's memory.

Some businesses with much larger quantities of information to process have turned to the computer. Large insurance companies began installing computers in their offices in the late 1950s. These firms had so much information on paper about their customers, they needed huge rooms just to store the data. Often, messengers on roller skates hurried from office to office in an effort to speed up the tedious jobs of processing and filing. Insurance agents found that they too could save a great deal of time and energy by using computers. By simply pressing a button, an agent can instruct a computer to print out a file in a few minutes. Before computerization, the same file may have taken days to collect and type out.



Typewriters have given way to computers in many offices.

In many offices, there are large numbers of letters and other documents that require typing. In these offices, the *word processor* has become a familiar feature. A word processor is a computer designed to accomplish the tasks normally performed by a typewriter. Even the simplest word processors on the market are much more efficient than standard typewriters. For example, making corrections on a typewriter can be time-consuming and messy. Using a word processor, a secretary makes all changes and corrections on the monitor before printing out the final copy. In addition, if later changes are called for, it is not necessary to redo the whole document, as was the case with the typewriter. The original text is stored in the machine, so the document can be recalled at any time. Using the keyboard and monitor screen, the changes are quickly made and the revised version is printed out on command.

Word processors can also be instructed to print as many copies of a document as desired, each addressed to a different person or company. Hundreds of documents can be stored on a single, small magnetic disk. Therefore, a great deal of time and space that used to be devoted to filing such documents can be used for more important tasks. Writers, editors, and other people who regularly deal with the written word also find the word processor an invaluable tool.

Computers in Banking

All modern banks are equipped with sophisticated computer systems. The amount of paperwork involved in banking transactions used to be enormous. Much of this paperwork has been eliminated by the use of computers. Each bank teller is equipped with his or her own computer terminal which can be used to access account information in seconds. A teller can complete a transaction many times faster than before and with far fewer errors.

Computers have also helped in the area of check clearing, or approval. Before computers, when a check traveled from bank to bank, it had to be physically processed at each bank by a teller or clerk. Checks took several days and sometimes even weeks to clear. Between 1950 and 1980, there was a 1,100 percent increase in the volume of checks written in the United States. With millions of checks being written each day, the old methods of processing them would have been extremely time-consuming and costly. Computers made it possible for banks to handle this huge processing load efficiently and economically.

Sophisticated computer systems have eliminated much of the paperwork that once was required in banking.

Computers also made banking more convenient through the introduction of Automatic Teller Machines, or ATMs. These devices are typically located in bank lobbies, supermarkets, shopping centers and hotels. ATMs offer bank customers twenty-four hour service and can perform many of the everyday procedures that normally would be handled at the bank. This means that banks do not have to hire as many people, which saves them a great deal of money.

An ATM customer is given a plastic card on which his or her personal identification number (PIN) has been magnetically imprinted. The customer inserts the card into a slot on the ATM and the machine reads the number off the card. The customer also uses a small keyboard to enter the PIN, which only he or she knows. This is to ensure that no one uses someone else's card. If a card is stolen, a thief can insert it into the slot but, without the entering of the PIN the ATM will not work.

Once the card and PIN are entered, the bank's computer automatically looks up the person's bank record. The customer then uses the ATM keyboard to enter the type of transaction and amount of money desired. Next, the computer reviews the customer's record and decides whether or not the transaction can be allowed. For instance, suppose the customer wants to withdraw one hundred dollars but has only seventy-five dollars in the bank. The computer informs the person, via a small screen on the ATM, that it cannot allow the transaction. The customer can then initiate a new transaction, perhaps asking to withdraw fifty dollars. In

Computers make check and credit card approval go faster.

Computerized Automated Teller Machines, or ATMs, offer bank customers 24-hour service and can perform many everyday bank procedures.

that case, the computer will approve the withdrawal and dispense the cash. The ATM even provides a written receipt of the entire transaction for the customer's records.

Yet another computerized banking service involves banks linking their computers to retail stores. The system is called Electronic Fund Transfer, or EFT. When a person wants to make a purchase, the store computer notifies the bank computer, which automatically deducts the money from the person's account. This allows a customer to shop without using cash, checks, or credit cards. The system is not only convenient for the customer, but also eliminates a great deal of check processing and other paperwork. EFT systems are expanding rapidly. Experts predict that most stores in the U.S. will be linked directly to banks by the early twenty-first century. People in banking refer to this as the coming of the "cashless, checkless society."

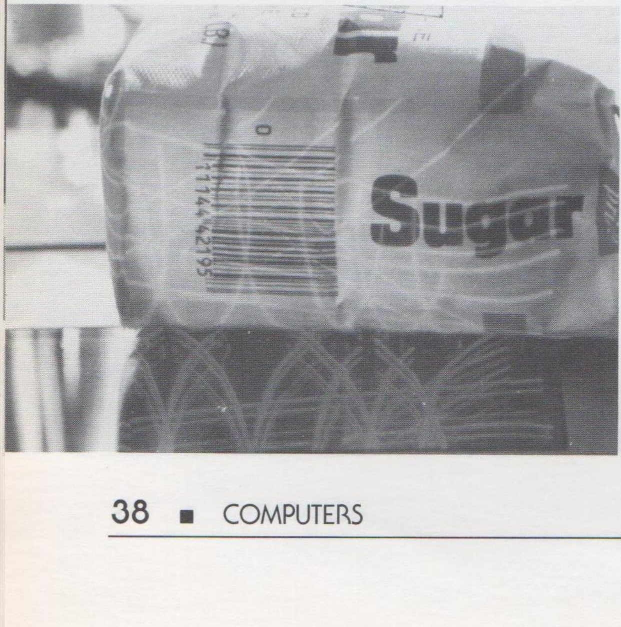
Computers in Supermarkets and Retail Stores

Many grocery stores are now equipped with computerized laser scanners. These devices allow items to be checked out much more quickly and accurately than with ordinary cash registers. Every product in the store is marked with a small band of black stripes called a *bar code.* The code is different for every item. The Supermarket Institute introduced this code, called the Universal Product Code, or UPC, in 1973. The checkout clerk runs each item across a scanner and a laser beam reads the bar code. The information is relayed to the computer's memory.The computer has been programmed to recognize which code stands for which product and automatically identifies each item. Next, the computer looks up the price, which has also been programmed in. The name of the product and the price appear on a small screen that can be read by both the customer and the clerk. When all of the customer's products have been scanned, the machine adds up the purchases and the total appears on the screen.

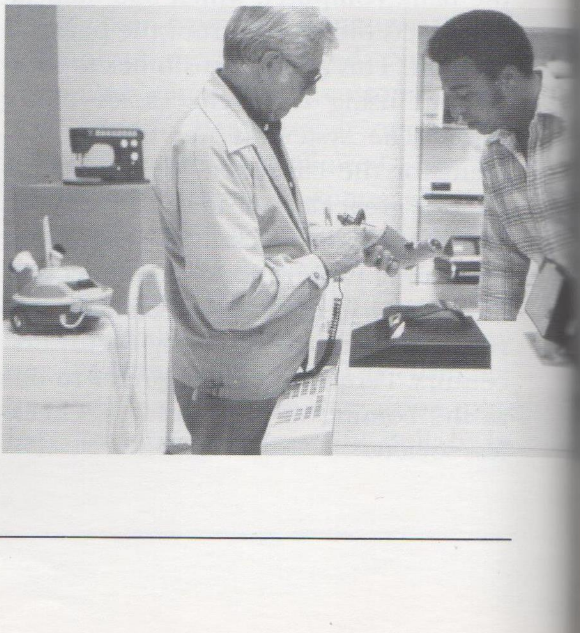
The UPC system also helps with inventory, a detailed list of the items on hand in the store. For instance, suppose there are two-hundred jars of Welch's Grape Jelly on the shelves when the store opens on Monday morning. Each time one of these jars is sold, the computer records it. At the end of the week, a store employee goes to a computer terminal and orders the computer to read or print out the number of jars sold. If 150 jars were sold, the employee knows the supply is low and immediately puts in an order for more jelly. This system obviously saves a great deal of time spent walking up and down store aisles and counting jars by hand.

The bar code system also helps keep track of inventory and purchases. A clothing store manager can see which items are most popular with information recorded in the store's computer.

Such computer inventory management works just as well in department stores and other retail establishments. When a person buys a pair of pants, for instance, a computer records the entire transaction. The machine keeps a record of how many pairs of pants of that particular style are sold in a given time period. This tells the manager of the store how many pairs are left. It also in-

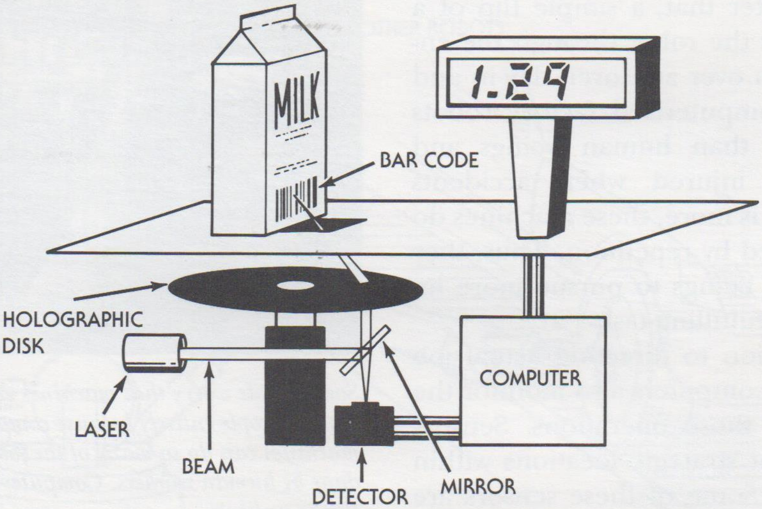


Computerized laser scanners read a bar code to allow grocery store items to be checked out more quickly and accurately than with ordinary cash registers.



A store clerk runs an item across a scanner and a laser beam reads the bar code, which will tell the customer the price and record other information for the store's records.

BAR CODE AND LASER SCANNER



A bar code is a set of numbers expressed in a series of black bars and white spaces. A wide white space stands for the number "1," and a narrow white space stands for "0." At a supermarket checkout stand a laser scanner reads the bar code. A mirror directs the light from a laser through a spinning holographic disk. The disk projects the light beam across the bar code, and only the white spaces reflect the beam back to a detector. The detector converts the pulses of the beam into an electric signal that goes to a computer. The computer then matches the code with a particular product and price, and the price appears on the display.

dicates which items sell the fastest and are the most popular. Before computers, compiling this sort of information was time-consuming and often inaccurate.

Computers in the Factory

For generations, many factory workers had to perform dull, repetitive, sometimes dangerous jobs by hand. For instance, some people welded together identical metal parts all day long. Others operated huge machines that endlessly pressed slabs of hot metal into prepared molds. Many of these jobs are now done by computerized robots. Factory robots are built with metal "arms" and "hands" that swivel and bend in various directions. Each robot is connected to a computer which is programmed to make it complete its task. A typical robot program might include hundreds, even thousands of separate instructions. Examples of such instructions are "tighten grasp on container," "move four inches to the right," and "tilt ninety degrees to pour hot metal."

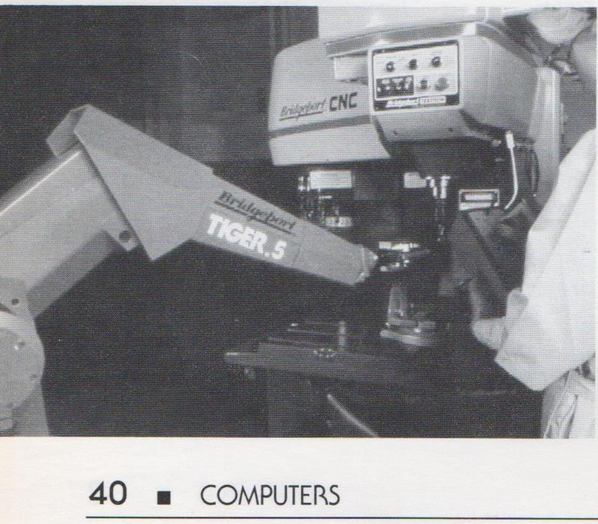
When a new program is instituted, a person "trains" the robot. This is done by moving the robot through the program one step at a time. Each movement is recorded in the computer's memory. After that, a simple flip of a switch sends the robot through the entire program over and over, day in and day out. Computerized factory robots work faster than human beings and cannot be injured when accidents occur. What is more, these machines do not get bored by repetition. Thus, they free human beings to pursue more interesting or fulfilling tasks.

In addition to directing actual job operations, computers also monitor the progress of those operations. Sensors are set up at strategic locations within the factory. Some of these sensors are activated by heat detectors, others by laser beams. The information from the sensors enters the computer, which sees that things are running smoothly. If something is wrong, the computer alerts a human supervisor, who makes the necessary correction.

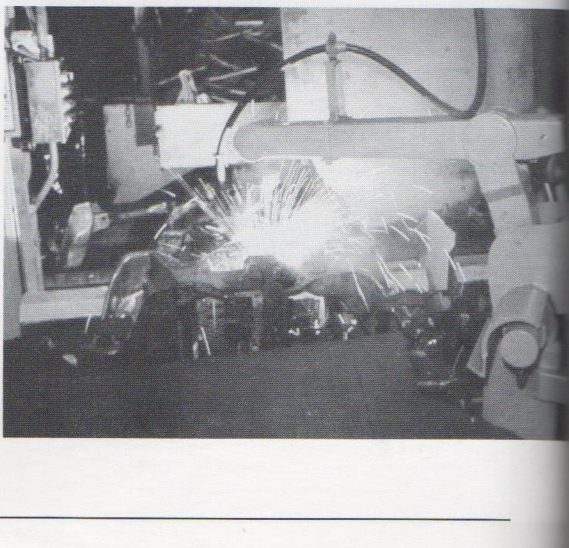
Computers control the refining of oil products from crude oil and the manufacture of steel from iron ore. They also direct the processing of crop fertilizers from minerals. Computers instruct machines to pour soft drinks into bottles and other machines to place caps on the bottles. Packaging and labeling operations are also often directed by computers.

Some people worry that machines eventually will replace people entirely because computerized machines can do so many of the jobs normally done by human workers. Computer experts say this is unlikely.

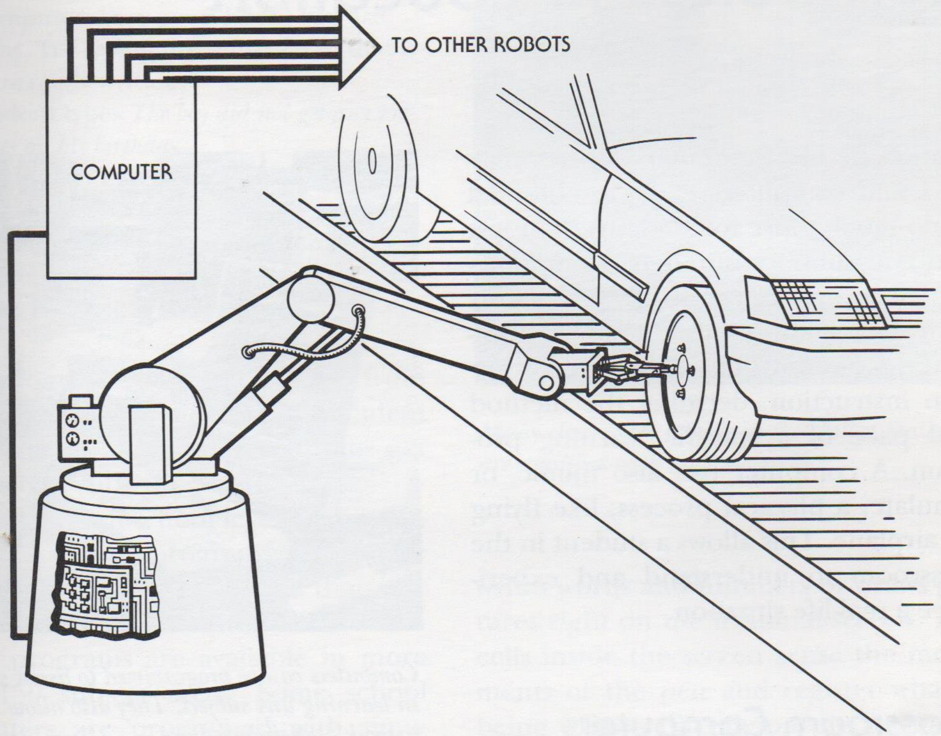
Computerized robots now do many dull, repetitive factory jobs once performed by human workers. Here, robotics is used for tooling.



Computers control the refining of oil products, the manufacture of steel and the processing of crop fertilizers. Computers also direct packaging and labeling operations.



COMPUTER-DRIVEN ROBOTS



Computers operate robots by sending thousands of "on" or "off" signals to switches on the robot every second. These switches control all of the robot's movements.

Because computerized machines can do many jobs normally done by human workers, some people worry that such machines will eventually replace people entirely. But computer experts point out that this is unlikely. They say that those humans who lose their jobs to computers can be retrained to perform new jobs. The new jobs might require levels of intelligence and creativity that cannot be imitated by any machines, including computers. Thus, the computer revolution is forcing some people to consider different, more challenging professions. And advances in computer technology constantly give birth to new jobs that did not exist before. Software designer, robot technician, and computer installer are examples of jobs brought about by the computer revolution. For every type of job a computer eliminates, several more are created.

In the business world, the bottom line is making money. Computers enable businesses to make more money and operate more efficiently. Therefore, people will continue to find new ways to use computers in offices, stores, and factories.

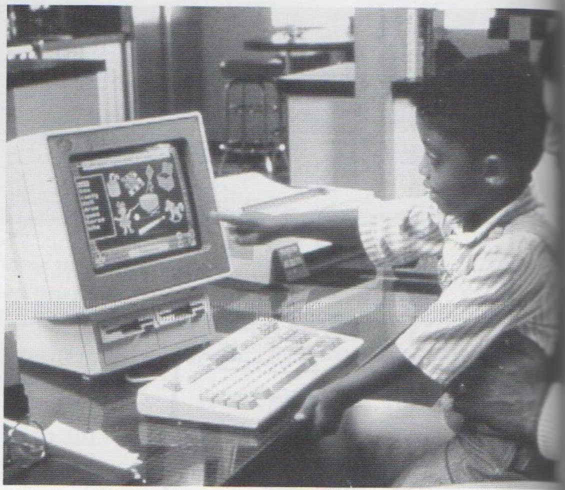
CHAPTER 4

Computers in Education

Educators and computer experts realized that computers had the potential to do much more for students than just add and subtract numbers. Computers can be programmed to assist students in learning any subject. Using a computer, a student can manage his or her own instruction, deciding the method and pace of a specific learning program. A computer can also mimic, or simulate, a physical process, like flying an airplane. This allows a student in the classroom to understand and experience a real-life situation.

Classroom Computers

Many elementary schools are now equipped with a central learning computer. Connected to this device are dozens, or sometimes hundreds, of individual classroom terminals. These terminals are tools in a system called Computer Aided Instruction, or CAI. In some schools, students use computers for about fifteen or twenty minutes a day. Other schools allow longer periods of computer instruction or break up the instruction into two separate periods. Decisions about computer use are made by individual school principals and classroom teachers. The educators decide which subjects are best supplemented by computer instruction. Often, the teachers prepare their own computer programs for individual classes.



Computers can be programmed to assist students in learning any subject. They also allow students to work at their own pace.

A typical computer-assisted learning situation begins with the appearance of an initial instruction on the terminal's screen. For instance, the computer most often asks the student to type his or her name. There then follows a back-and-forth exchange between the student and the computer. Following is the beginning of such an exchange:

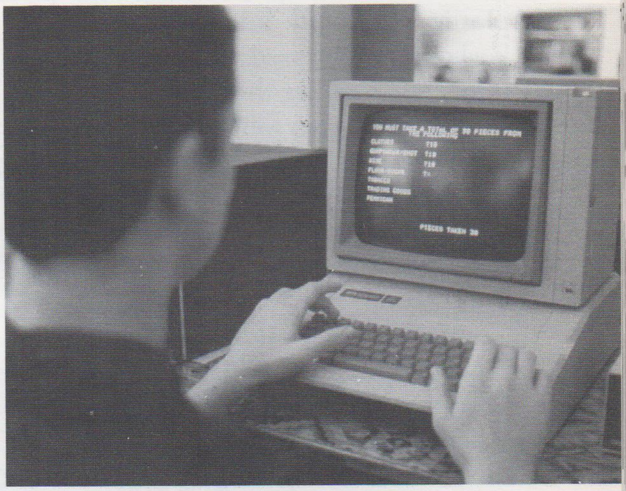
> Computer: Please type your name and press *return.*
> Student types *Ellen.*
> Computer: Hello, Ellen. We're going to look at some sentences together. We're going to try to see which sentences are correctly written. Press *return* to see the first sentence.
> Student presses *return.*
> Computer: *The boy did not get no presents*

on his birthday. Is this sentence correctly written? Type *yes* or *no.*
Student types *No.*
Computer: Very good Ellen! You are right. Try typing the sentence so that it is correctly written.
Student types *The boy did not get any presents on his birthday.*
Computer: Excellent! You recognized that *did not get no* is a *double negative.* That is considered incorrect word usage.
Now, Ellen, let's try another sentence.

Most programs of this type ask from twenty to thirty questions. As the student progresses in ability, the programs get increasingly difficult.

On the high school level, computer-assisted learning programs are similar to but much more advanced than the elementary versions. Thousands of different programs are available in more than 150 subject areas. Some school computers are programed with simulated voices. Programmers record a person repeating all the basic sounds of the English language and incorporate those sounds into the computer. The machine then pieces together the appropriate sounds to form words and sentences. These machine voices are especially effective in teaching languages because the student can hear the words spoken in the correct manner. And because each student at a terminal moves at his or her own speed, computerized instruction is individualized. By contrast, it is impossible for one human teacher to offer individual, one-on-one instruction to each member of a class of thirty students.

Many school computers have special screens equipped with light-sensitive cells. Using a *light pen,* a small wand that emits a beam of light, a student writes words and numbers or draws pictures right on the terminal screen. The cells inside the screen sense the movements of the pen and register what is being written directly on the screen. A *mouse* is a similar device consisting of a



Many elementary schools in the United States are equipped with computers.

Computer programs get increasingly difficult as a student's ability progresses.

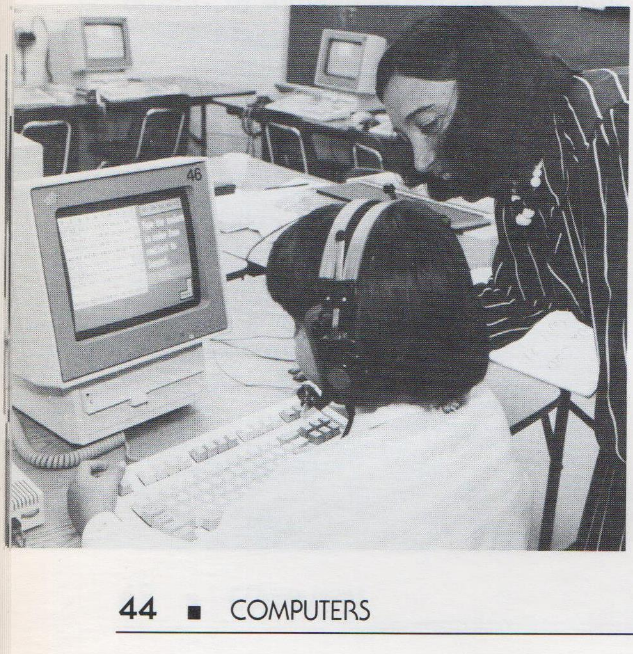
plastic ball built into the computer's keyboard or housed in a separate container. By twirling the mouse in various directions, a person can create complex patterns and pictures on the terminal screen. Such systems are popular with art and science students who watch their mechanical designs come to life on the screen.

Many colleges use an even more advanced computer-learning system called Computer Managed Instruction. This system allows a student to actually design the course of instruction to fit his or her own particular needs. For instance, suppose the teacher has assigned the student to learn about ancient Greece. The computer gives the student a set of choices for the opening lesson. These might be to read an article, watch a film, or listen to a taped lecture.

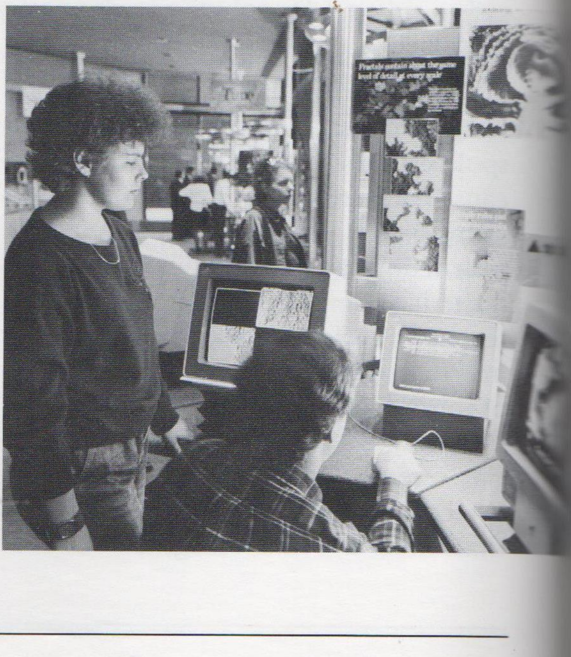
After completing the assignment, the student returns to the computer and reviews the material learned. If the student wishes, the computer can administer a quiz. Afterward, the machine offers another set of choices for the next lesson. The student moves through the course of study at a comfortable pace and chooses the learning methods he or she finds the most effective. All the while, the teacher monitors the student's progress and suggests further programs and options.

Computer Simulations

A computer *simulation* is a model of a real-life situation that a computer is programmed to act out. For example, a student might want to study a natural process that normally happens slowly, like erosion, the process by which wind, rain, and sun wear away soil and rocks on the earth's surface. A special program speeds up the process on the

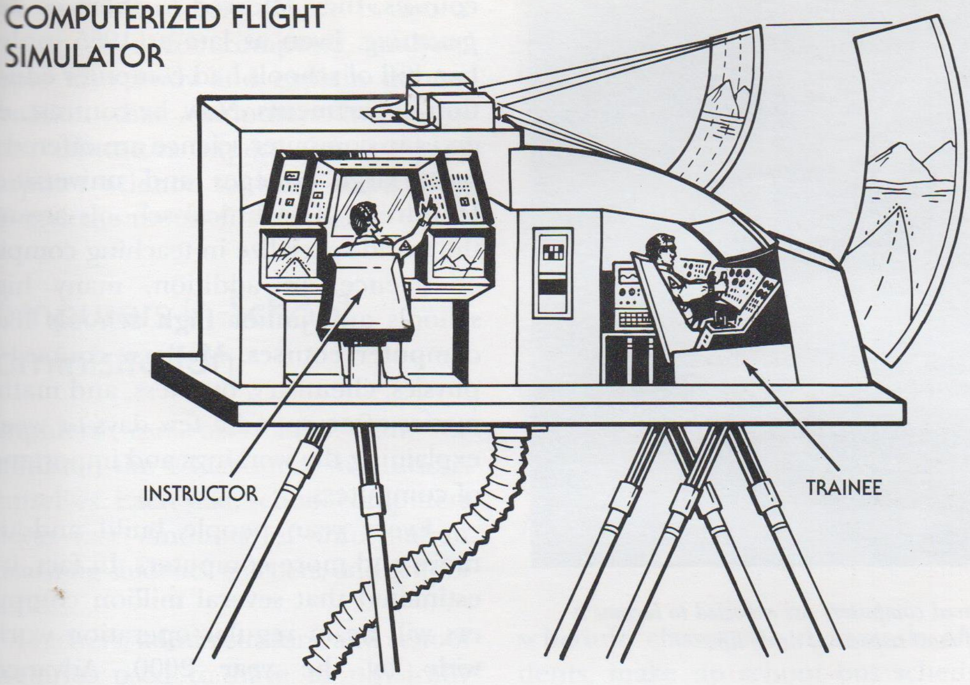


Some school computers are programmed with simulated voices.



High school students use computers to study many subjects including language, math and science.

COMPUTERIZED FLIGHT SIMULATOR

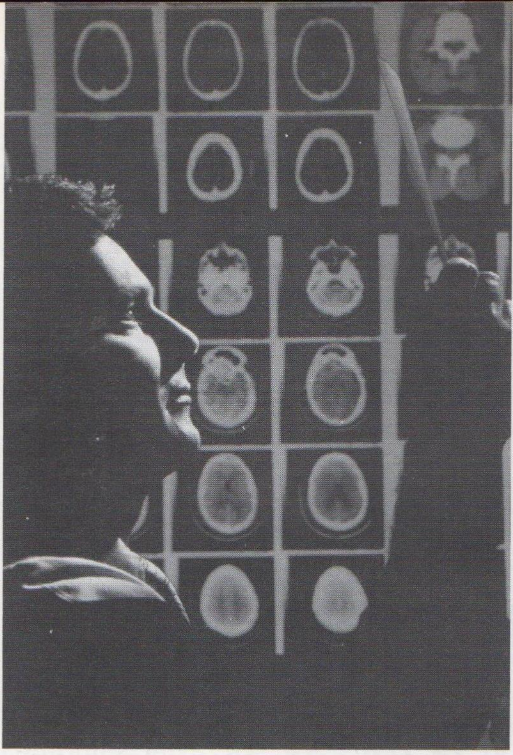


A computerized flight simulator is a safer and more economical way to train pilots than using real planes. From the instructor's station, an instructor commands the computer to imitate landings, flights, and takeoffs in all kinds of conditions. It runs projectors that direct scenes onto a system of curved screens and mirrors, which make the scenes appear a long distance away. As the trainee operates the controls in the cockpit, the computer responds to his actions by making the simulator rock and tip like a plane in flight.

computer's screen. In only a few minutes, the student is able to see the various effects of erosion on a forest over the course of many years.

Using a computer simulation, a person can learn the fundamentals of operating a mechanical device. For instance, someone learning to drive a car can watch one of many computerized driver's education simulations. One program might help the person go through the steps of starting the car and shifting gears. Another program might test the person's ability to make decisions in heavy traffic or emergency conditions. Similar programs exist for learning to fly airplanes. These sorts of computer simulations save money because the basics can be learned without wasting gasoline and instructor time. The simulations are also safer since mistakes made while learning do not result in crashes.

There are many other uses for computer simulations. People studying to be doctors can watch simulations of blood circulation or cancer growth. Business students can build model companies and see what happens when they apply



Advanced computers are expected to become a part of most aspects of daily life.

various management strategies. Science students can observe computer simulations of volcanoes to study the processes of volcanic explosions.

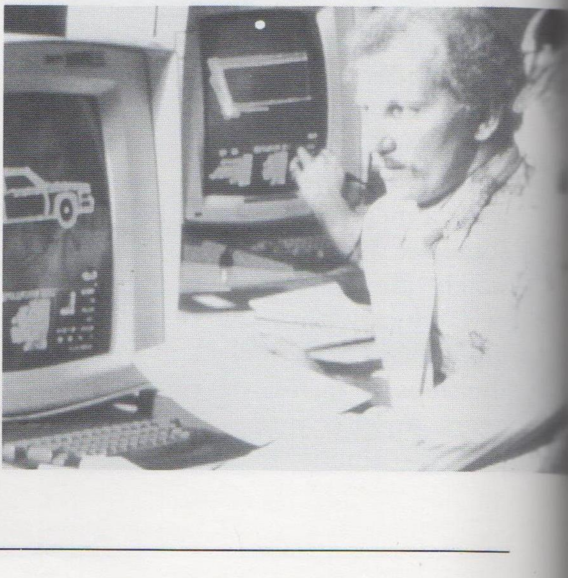
Clearly, computers have become powerful tools to help people learn about themselves and their world. But computers are not just aids to instruction—they are also the subjects of instruction.

Studying Computers

The study of computers—how they are designed, operated, and programmed—is called *computer science.* In the 1980s, some people began referring to the study of computers as *information technology.* Both terms are widely used and accepted. Before 1950, the study of computers did not exist in any college or technical school. When people first instituted such courses, they referred to them as *data processing.* Even as late as 1965, only a handful of schools had computer education departments. Now, by contrast, degrees in computer science are offered at most large colleges and universities. Hundreds of technical schools around the world specialize in teaching computer science. In addition, many high schools and junior high schools have computer courses. Modern courses in physics, chemistry, business, and mathematics often spend a few days or weeks explaining the workings and importance of computers.

Every year, people build and use more and more computers. In fact, it is estimated that several million computers will be in regular operation worldwide by the year 2000. Advanced computers are expected to become a part of most aspects of everyday life. All this computer activity is creating and will continue to create a need for trained computer experts. These in-

Computer simulations can help a person learn the fundamentals of driving a car and flying an airplane.



clude computer designers, programmers, and instructors. There is also a growing need for computer analysts, people who study and explain the information that computers turn out. Thus, educators expect the study of computer science to keep expanding well into the twenty-first century.

Computers in School Administration

Computers can also help run, or administer, the educational institutions themselves. Each year, school computers process vast amounts of information concerning students, teachers, and school business.

Teachers, administrators, and school secretaries used to have to physically compile and record data concerning hundreds or thousands of students. Over the years, more and more schools installed computers to process this data. School computers keep records of the vital statistics of students. Computers also record student medical histories, attendance records, and grades. Similar records are kept about teachers and other school personnel, including their college transcripts and job histories. School computers can do many other jobs. They keep track of the employee payroll, as well as the amount of money the school spends on books, sports uniforms, heating fuel, and other necessities. Computers routinely schedule classes for thousands of students, make up school bus schedules, score tests, and print out report cards. In general, computers do many of the boring, repetitive, time-consuming tasks that school personnel used to do.

Computers store student attendance and medical records. They also store records of grades, personnel, payroll, and purchases.

What is the result of computers freeing people from having to do these tasks? Schools and colleges offer students more and better services. Teachers spend less time on paperwork and more time teaching. Principals and their staffs can devote more time to problems of individual students. And school records are more complete and accurate. By helping schools to run more smoothly, computers have increased the quality of education at all levels.

■ ■ ■ ■ ■ ■ ■ ■ ■ CHAPTER 5

Computers in Law Enforcement

One day in 1972, a state policeman in Idaho stopped a car for speeding. Had the incident occurred ten years earlier, the officer might have merely issued the driver a speeding ticket and sent him on his way. But Idaho had recently installed a statewide computer system linking all city and county police departments. In addition, the state police computer was tied into the FBI's National Crime Information Center, or NCIC. The FBI computer center had records of millions of individual crimes that had been committed all over the country.

The officer routinely radioed the speeding car's license plate number to the state police. The police and FBI computers immediately searched their memories for any information on that plate. In less than two minutes, the officer was advised to arrest the driver of the car. The computers discovered that the license plate had been stolen from a car in Missouri. The car was stolen in Alabama. The driver himself was wanted by the FBI for grand larceny. Had it not been for police use of computers, the criminal would have escaped.

A nationwide computerized crime information network assists police in identifying crime suspects.

Computerized Police Network

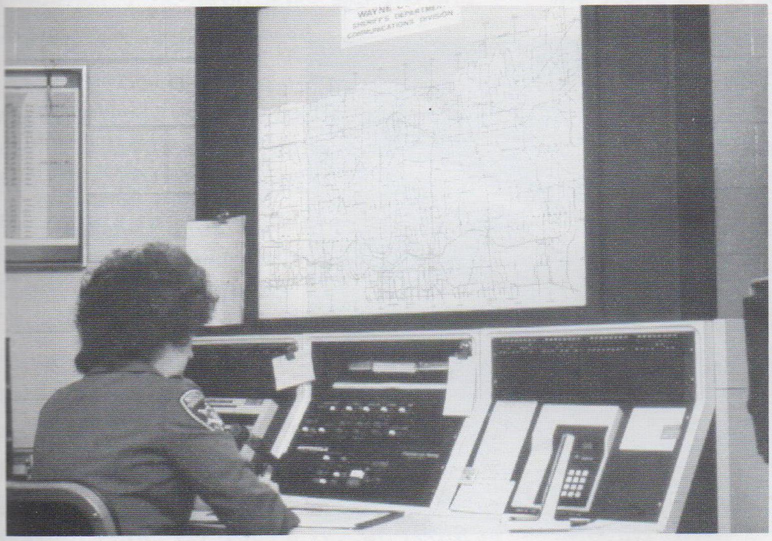
No one knows when and where a crime will be committed next, so police officers must be ready at all times to deal with criminals. This means that information about suspected criminals must be processed and made available to the officers very rapidly. Once again, the computer has proven to be an invaluable tool for sorting through vast amounts of information.

In 1962, Chicago, Illinois became the first American city to install a computer system to check for stolen cars. All licensed drivers and plate numbers were listed in the system. Known car thieves and stolen plates were also listed. Like the officer in Idaho, Chicago police checked suspicious plate numbers and drivers. The system was so successful that many other large American cities installed similar systems shortly afterward. The Chicago computer now lists hundreds of thousands of names and vehicles, and officers run checks through the system more than two-thousand times a day.

California was one of the first states to use a computer to keep track of the sales of guns and other weapons. Stored in the computer's memory are the records of persons in the state who own guns. Also stored are ID numbers and descriptions of reported stolen weapons. The computer can tell an officer in seconds whether a particular gun has been stolen. Computers are also used by city police departments to keep track of parking violations. The computers are often programmed to send bills and warnings to the violators.

Police can spot patterns in thefts and other crimes with the help of information stored in their computers. Computers also keep track of parking violations.

Another important use for police computers is to aid detectives in solving crimes. Many criminals use the same general method each time they commit a crime. For instance, a burglar might break in through basement windows and only steal jewelry. A murderer might single out victims of a certain age group and repeatedly use the same kind of weapon. Police call such repeated routines a criminal's "method of op-


WAYNE COUNTY SHERIFF'S DEPARTMENT COMMUNICATIONS DIVISION

Police computers are programmed with the details of crimes committed in their areas. The time, place, and general nature of the crime is stored in the computer's memory.

Police emergency networks all over the United States use computers to speed help to the scenes of crimes, accidents, and fires.

Police can direct computers to compare the details of one crime with the details of another. If the computer spots a pattern, it can print out the names and backgrounds of various suspects.

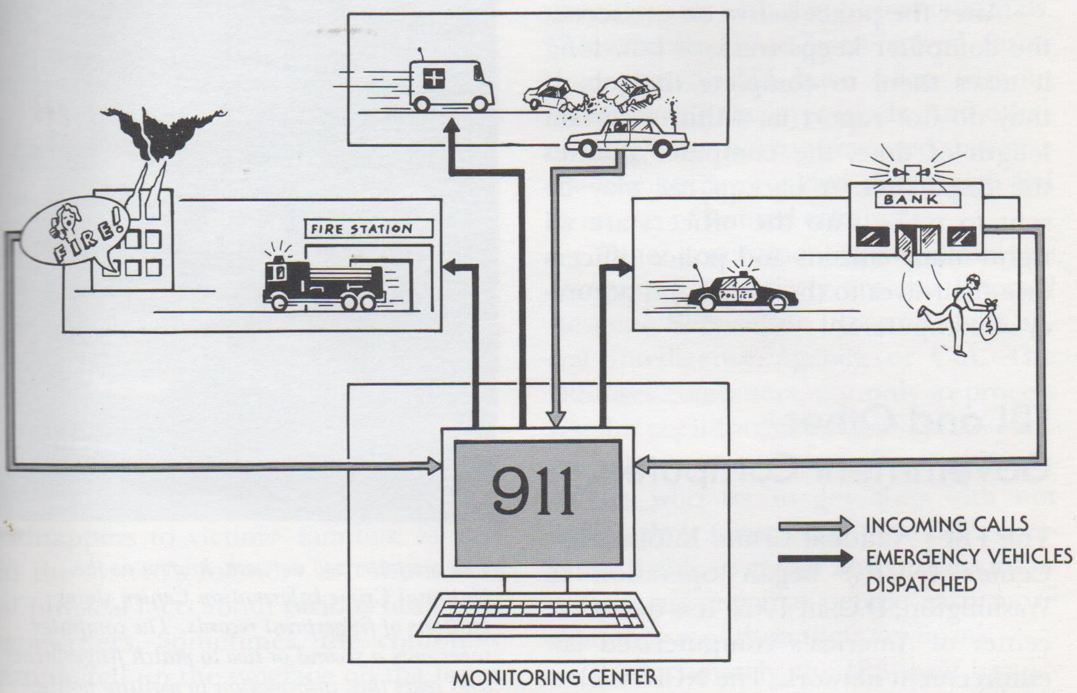
eration," or MO. Police computers are now programmed with the details of all crimes committed in their respective areas. The time, place, weapons used, and general nature of each incident is stored in the computer's memory.

When a new crime is committed detectives can order the computer to compare the details of the incident with those of other similar incidents. If the computer spots a pattern, it notifies the detectives. The machine then prints out the name and background of those criminals who use the same MO. The detectives can compile a list of suspects and call them in for questioning. Often, the guilty person is on the computer's list and the detectives need look no further.

Police emergency networks all over the United States use computers to

When an emergency call comes into police and fire dispatchers, computers take only seconds to find the nearest patrol cars or fire stations. Sometimes, police and firefighters respond in as little as ninety seconds.

911–CENTRALIZED EMERGENCY SERVICE



A central computer keeps track of the whereabouts and availability of all emergency vehicles and personnel on duty in a city. When a caller dials 911 and reports a fire, the computer identifies the nearest fire stations and the activity of the firefighting personnel. If a serious traffic accident is reported, it dispatches the nearest available ambulance. And if a crime is reported, it locates police personnel closest to the scene of the crime.

speed help to the scenes of crimes, accidents, and fires. The phone number 911 has become the standard emergency telephone code everywhere. The police dispatch system installed in New York City in the 1960s was called SPRINT. This system is regularly updated with information about the locations of patrol cars and other emergency vehicles. When a call comes in asking for assistance, the police operator types a code on a computer terminal keyboard. A fire has a certain code. So does a rescue request. Operators quickly relay such calls to the appropriate agency.

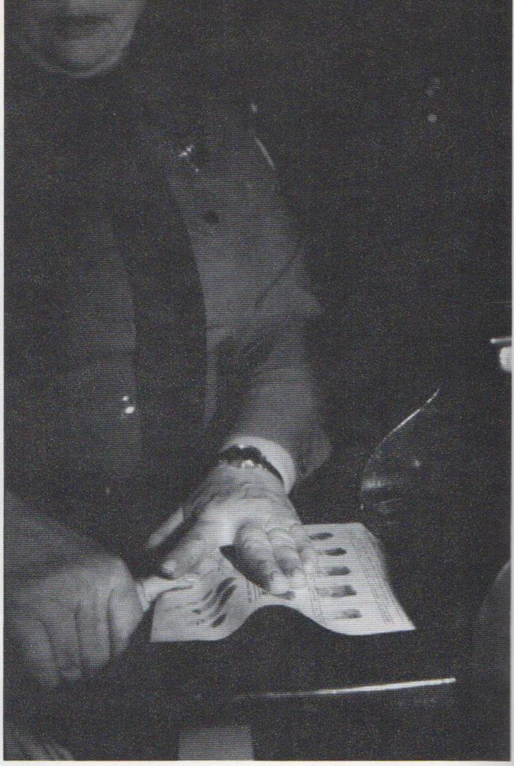
Robberies, car accidents, and other kinds of police emergencies also have codes. For instance, the number 10-13 indicates that an officer needs help. The police operator also keys in the location of an emergency. In seconds, the computer searches through its memory and finds which patrol cars are located closest to that location. The police dispatcher calls those cars on the radio and informs them of the emergency. Total response time, from the 911 call to the arrival of police, is sometimes as little as ninety seconds.

After the police arrive on the scene, the computer keeps track of how long it takes them to complete the job. If they do not report in within a certain length of time, the computer notifies the dispatcher. A backup car may be sent to make sure the officers are all right. Many citizens and police officers owe their lives to the speed and accuracy of computers.

FBI and Other Government Computers

The FBI's National Crime Information Center (NCIC) began operation in Washington, D.C. in 1967. It is the nerve center of America's computerized law enforcement network. The NCIC is electronically linked with more than two thousand local police computers all over the United States and Canada. Stored in the FBI computer's memory are facts about wanted persons, stolen property, break-ins, and license plate numbers. Millions of separate records are compiled. Thousands of requests come in each day from police departments asking the NCIC for information checks. The average request is answered in two to ten seconds. This great speed enables a police officer located a thousand miles away to get the data needed to make a quick arrest.

The NCIC also stores huge numbers of fingerprint records. When a police officer in Florida fingerprints a suspect, computer operators record the prints with an *optical scanner.* This device uses laser beams to examine the prints. The images are then encoded and stored in a computer. The encoded prints can be electronically transferred to the NCIC computer. There, the prints are compared to millions of others in the machine's memory. Within one or two seconds, the computer discovers any potential match-ups and relays the information back to the officer in Florida.



The computerized network, known as the National Crime Information Center, stores millions of fingerprint records. The computer takes only a second or two to match fingerprints and relay that information to waiting police.

Also on record in the FBI center are records of guns and their identifying characteristics. These records can be matched up with information gathered by local police departments. For example, the NCIC computer might show that a weapon used in a robbery in Oregon was purchased in Georgia by a certain person. The police in Oregon now have a suspect to find and question. The NCIC system can also help when typed ransom letters are sent by

The Internal Revenue Service uses computers to process regular tax information and compile data on tax evaders.

kidnappers to victims' families. Stored in the system's memory are thousands of physical facts about various brands of typewriters. Sometimes, the computer can match up the typeface on the letter with a specific brand and model. The police can then check with stores to see who bought that model in a certain city and time period.

It is estimated that the FBI computer center has benefited American society in numerous ways. Police officers' lives have been saved because they had information that warned them they were dealing with dangerous criminals. Many crimes have been solved faster than they would have been without NCIC, saving taxpayer funds. And other crimes have been prevented because the computer provided data which led to arrests of wanted criminals.

Other government agencies that use computers extensively are the Internal Revenue Service, or IRS, and the Central Intelligence Agency, or CIA. The IRS uses computers, not only to process regular tax information, but also to compile data on tax evaders. These are individuals who try to get away with not paying their taxes. Often, the IRS's computer is able to gather and process information proving that people earn more than they report on their tax forms.

Unfortunately, the IRS itself has occasionally used the great power of the computer for illegal purposes. For instance, between 1969 and 1975, the IRS secretly collected information about the private lives of more than 400,000 American citizens. This information in-

Some computer experts have used their knowledge to steal money from banks by bypassing security codes and then transferring money from one account to another.

cluded facts about people's love lives, drinking habits, and which politicians they supported. This unethical operation was stopped. But it shows how easy it can be for people to use a huge computer information system in an improper manner.

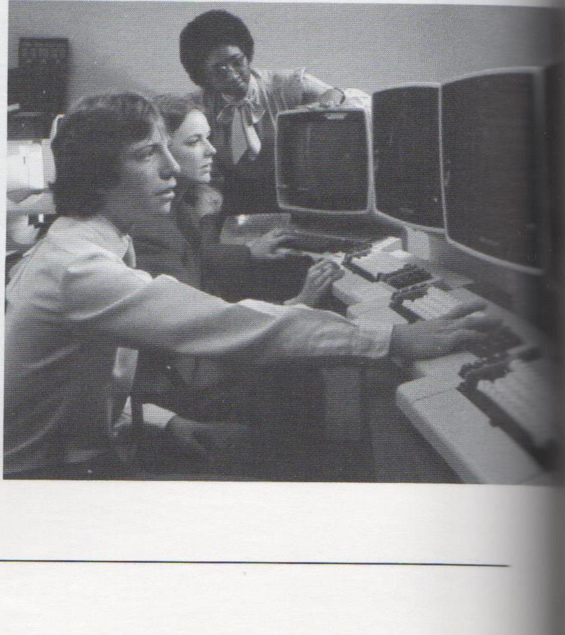
The CIA is a branch of the U.S. government that investigates threats to the security of the country. Like other law enforcement organizations, the CIA uses computer networks to gather information on criminals or spies. Not much is known about CIA computer systems because almost everything about that agency is kept secret from the public. Computer experts say that the CIA computers must be similar to the FBI's NCIC computers.

Computer-Related Crimes

Computers are not only used to fight crime—these modern super tools are sometimes used to commit crimes. One type of computer crime that is becoming increasingly common is the theft of electronic funds. As explained earlier, many banks and other institutions use the EFT system to transfer money from one place to another. Some computer experts have taken advantage of their knowledge of the machines to steal this money. The thief breaks into the bank's computer system by figuring out how to bypass the computer's security code. The code is a special number or password that is supposedly known only to bank officials. The computer will not operate without the code. Having broken into the system, the thief orders the computer to transfer funds from people's accounts into his or her own account. The next day, the thief withdraws the money and closes the account. Sometimes these criminals are caught and sometimes they are not. Banks and computer designers are constantly working to devise tighter security systems for computers. So far, no totally foolproof system has been discovered.

Another growing computer-related crime is the spreading of *computer viruses, worms,* and *bombs.* These are destructive computer programs which are designed to disrupt the normal functioning of a computer. Just as a biological virus can make people sick, a computer virus can make a computer sick. The virus program enters the computer and, using machine language, gives new orders to the control unit. Affected by the virus, the control unit directs the virus program to duplicate and attach itself to other stored programs. This causes great confusion in the memory unit. Every time a person wants to recall and print out some in-

Banks and computer designers constantly try to devise tighter security systems for computers. So far, no foolproof systems have been found.



formation, that information contains the extra data from the virus. In order to get rid of the virus, the computer has to be completely reprogrammed.

An unusually destructive computer virus is called a computer worm. A worm duplicates itself so many times that the entire computer system becomes clogged. The workings of the system slow dramatically or even halt completely. A computer bomb is a virus that is designed to erase all the information in a computer's memory.

Computer viruses pose a danger to people as well as computers. For instance, if all the records of a medical computer were suddenly lost, doctors would lose vital information about their patients. Some of these patients might die. Another danger of computer viruses is that they can spread from one computer to another. This is because most large computers are electronically connected to many smaller computer systems. For example, the FBI's NCIC system is tied in with thousands of separate police computers. So, a person can feed a virus program into one computer and watch that machine infect all the computers it is connected to. In January, 1986, a software distributor in Pakistan created the "Pakistani Brain" virus. Thousands of IBM computers around the world became infected and the virus erased their memories.

In December, 1988, more than six-thousand computers linked by the Internet computer network became infected with a destructive computer worm. Computers all over the U.S. were put out of action for two days and many lost all their stored data. Detectives managed to trace the path of the virus back to its source. They arrested a twenty-four-year-old Cornell graduate student, Robert Morris Jr. Morris was tried in January, 1990, and found guilty of designing and releasing the crippling computer worm. His sentence could be five years in prison and a $250,000 fine.

Robert Morris Jr. was found guilty of designing and releasing a crippling computer worm that damaged stored records in computers all over the nation.

Many computer programmers are now guarding against the damaging effects of computer viruses. They are duplicating the memories of their computers on magnetic disks or tapes. If a virus wipes out a machine's memory, programmers can quickly reprogram the computer with the duplicate data.

Law enforcement officials constantly learn new ways to use computers in fighting crimes. At the same time, criminals find ways to use computers in committing crimes. Like any mechanical device, a computer can be helpful or harmful, depending upon the person who uses it.

CHAPTER 6

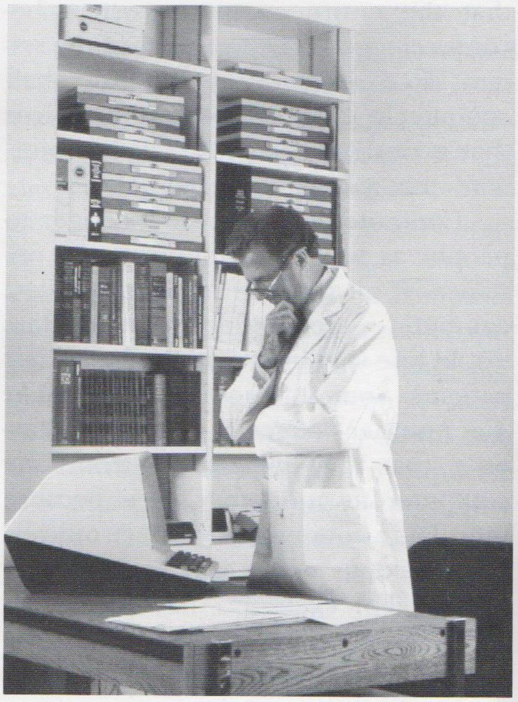
Computers in the Medical World

Doctors use many tools to help make sick people well. Such tools include the stethoscope, microscope, X-ray machines, and artificial heart. In the 1960s, some doctors and medical researchers recognized that the computer might also become a useful medical tool. All through the 1970s and 1980s, people discovered new ways to utilize computers in health care. They found that computers can aid in the study of heart disease and cancer. The machines can help train doctors, nurses, and other hospital personnel. Computers can also keep track of a patient's pulse, temperature, blood pressure, and other vital functions. And computerized lab equipment speeds up the processing of blood, urine, and tissue tests.

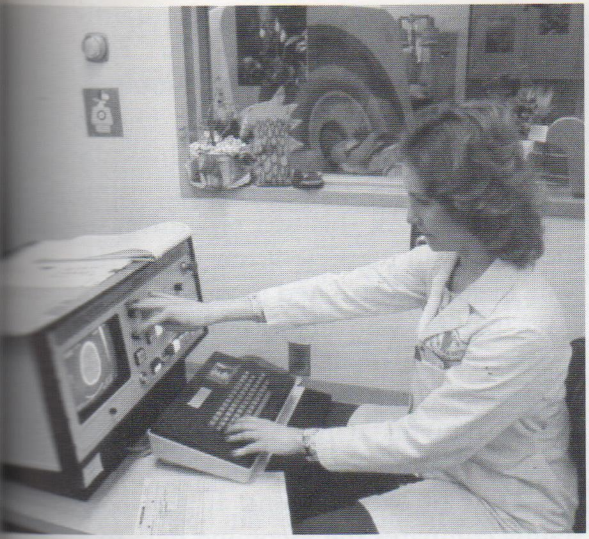
The administrative functions of hospitals can be handled by computers. These functions include payroll, billing, inventory control, and patient records. Thus, hospitals run more smoothly and doctors and nurses can spend more time with their patients. As a result, computers have helped save thousands of lives and improved the quality of care for people who are seriously ill. An example of such computer-aided health care is patient *diagnosis,* the identification of a disease or physical condition.

Diagnostic Computers

Doctors know that each disease or condition has its own characteristic physical signs, called *symptoms.* For example, some of the symptoms of the flu are headache, sore throat, and a runny nose. Sometimes, two or more diseases can have many similar symptoms. This makes it difficult for a doctor to diagnose exactly which disease a person is suffering from. Many thousands of diseases and their symptoms are now known to medical science. So, it is impossible for even the best doctor to instantly recognize one disease from another.



Computers aid in the study of heart disease and cancer and help train doctors and nurses and other hospital personnel. Computers also help doctors diagnose diseases and other physical conditions.



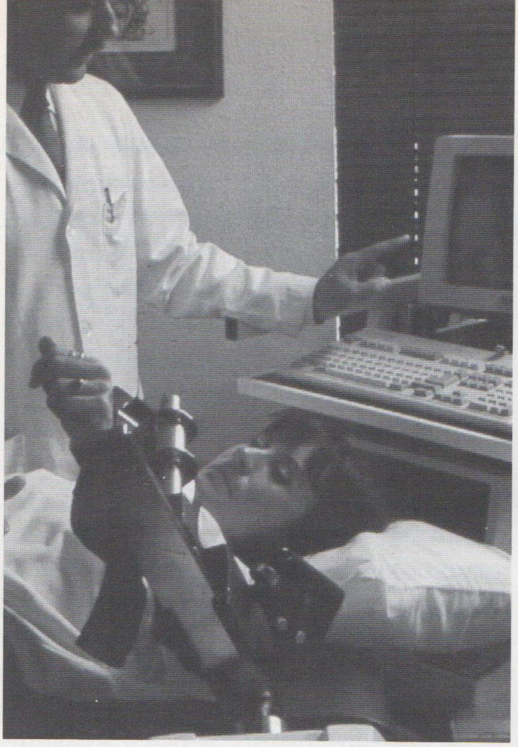
Some computers help doctors see inside a patient's body and then analyze the information obtained from that view.

Before the advent of a computer, a doctor examined a patient and noted the person's symptoms. Often, the doctor consulted medical books that listed the symptoms of known diseases. After deciding which disease the person had, the doctor looked up the known treatments for that ailment. Next, the doctor searched through other books which listed the latest medical drugs which might help in the treatment. Finally, in more serious cases, the doctor discussed the diagnosis with fellow physicians to make sure the treatment was correct. All these steps obviously took a great deal of time. Because a computer processes information far more quickly than people can, it eliminates much of this time.

A doctor can now sit down at a computer which has been specially programmed with all the diseases, symptoms, treatments, and drugs known to medical science. The doctor types in the symptoms he or she has found in a patient. The computer's monitor screen displays a list of diseases that fit those symptoms. Next, the doctor might ask the computer why it has listed a certain disease. The computer answers by explaining what is known about that disease and how it produces the symptoms. The doctor then might want to dig deeper. Perhaps the doctor commands the computer to compare the symptoms of one disease with those of another. Eventually, the computer supplies all the necessary information concerning treatment and drugs. In only a few minutes, the doctor completes the diagnostic process that once might have taken hours or even days.

A machine cannot replace a doctor. A human being still weighs all the evi-

Thousands of diseases and their symptoms are now known to medical science. Computers help doctors distinguish one disease from another more quickly.



Computerized monitors help nurses and doctors keep track of important bodily functions. They also alert medical staff in case of emergencies.

dence and makes the decision that could save a life or make someone well. But computers help the doctor, and ultimately the patient, by sifting through volumes of information in mere seconds.

Computers that Monitor Patients

Most patients in hospitals do not need to be constantly checked, or monitored. But those with serious conditions, such as heart disease or kidney failure, require regular monitoring. The slightest change in their conditions might signal the beginning of a life threatening situation.

In the days before the computer, nurses and doctors had to repeatedly make the rounds, checking a seriously ill patient's blood pressure and rate of breathing. They also had to constantly measure such variables as heart rate, body temperature, and urine output. The data from these periodic checks had to be written down and physically compared to the figures from previous monitorings. All this was repetitive, tedious, and an inefficient way to use the time of specially trained personnel.

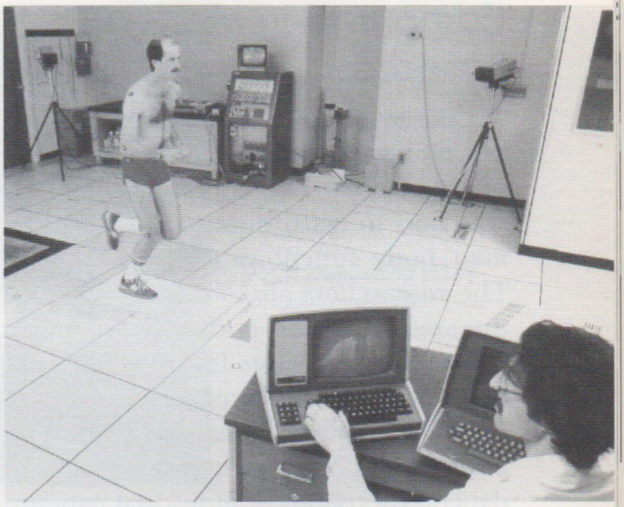
A patient who needs monitoring is connected via small tubes and wires to a computer. One computer can monitor several patients at the same time. The machine keeps track of all the bodily functions of each patient. It also constantly compares the incoming data to a set of "normal" figures supplied by the doctor. The system displays the data on a monitor screen beside the patient's bed. Sometimes, the data are simultaneously shown on a second screen at a central nurse's station. In this way a nurse can watch the patient closely without having to repeatedly enter the patient's room. In addition, when commanded, the computer prints out all the data collected about the bodily functions.

The computerized monitor also alerts medical personnel in an emergency. If any of the monitored functions register abnormally high or low, the computer sets off an alarm. The appropriate treatment can be administered immediately, avoiding further complications. Before the use of computer monitoring, if a patient had a serious setback halfway between rounds, the nurses had no way to tell. By the time of the next round, it was sometimes too late to help. Thus, computer monitoring can save a patient's life. In fact, hospitals estimate that the use of computer monitoring systems has cut the number of in-hospital deaths by more than one half.

Computers and Heart Disease

Many of the patients admitted to hospital emergency rooms are people with severe chest pains. Often, such pain is a symptom of a heart attack. The speed of the diagnosis can, in many cases, decide whether a person lives or dies. A doctor or nurse injects such a patient with a liquid that clings only to healthy heart tissue. The doctor then aims a special camera at the person's chest. This camera uses gamma rays to see inside the patient's body and show the doctor how the injected substance moves. The camera is connected to a computer which registers a color image of the patient's heart. As the healthy areas become coated with the injected substance, they register as light colors. The uncoated damaged areas register as darker colors. The doctor studies the computer image and decides how serious the situation is. The appropriate treatment is then given.

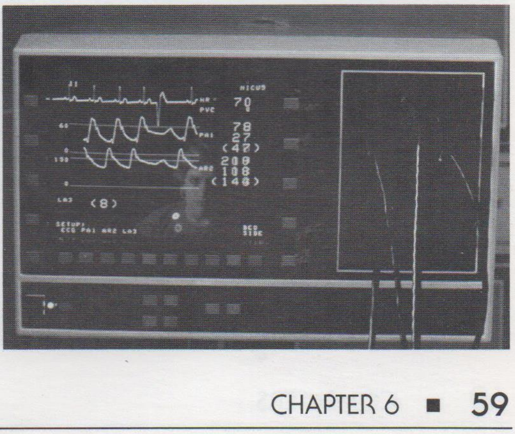
Computers are also used to analyze the information recorded by an electrocardiogram, or EKG. This machine measures the electrical impulses produced by a person's heart. Normal hearts give out small, steady electrical impulses. A cardiologist, a doctor who specializes in studying the heart, attaches measuring devices to the patient's chest. These devices record the EKG. A computer has been programmed with information from tens of thousands of EKGs. The machine knows what readings are considered normal for people of different sexes, ages, and body weights. The computer compares the patient's EKG to the others in its memory and prints out an analysis for the doctor to study.



Computers help analyze a patient's physical condition.

EKG data can be transmitted via telephone lines to hospitals or clinics hundreds of miles away. This means that a rescue team in a remote area can record a victim's EKG, then send it to a distant hospital. There, a doctor can feed the data into a computer and get a detailed analysis in a few seconds. The doctor can then relay instructions for treatment to the members of the rescue team.

Electrocardiograms, or EKGs, measure electrical impulses produced by the heart. Computers then help doctors analyze that information.



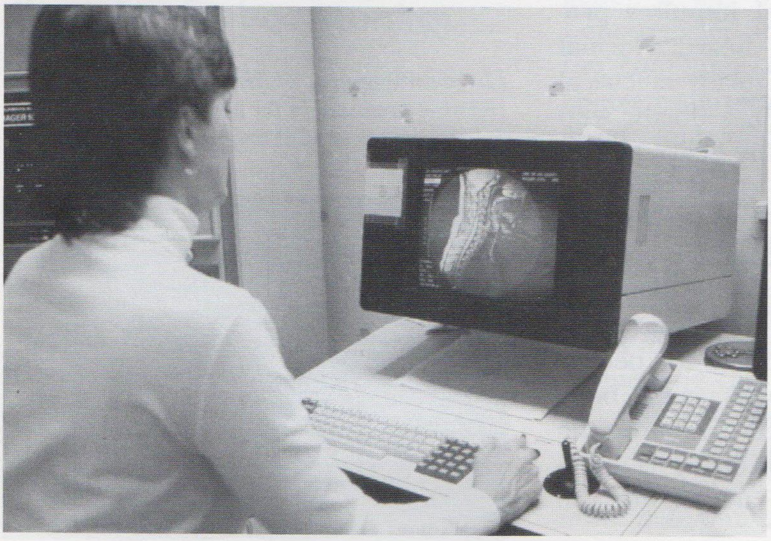
Computers in Medical Research

All modern medical research centers are equipped with sophisticated computer systems. The computers help researchers to learn how and why the human body functions the way it does. The researchers also study how various diseases affect the body. All this information helps doctors find the causes of diseases and devise cures and treatments.

Most medical research involves recording and comparing vast amounts of data on thousands of individual patients. As in other fields where large masses of data must be processed and studied, computers save people much time and energy. For example, a great deal of research is presently being done on *chromosomes.* These are microscopic chains that exist inside human cells. Chromosomes determine most physical characteristics, like eye and hair color, and right- or left-handedness. Scientists have found that many physical and mental disorders are the result of abnormal chromosomes. Examples are muscular dystrophy, which cripples the muscles, and hemophilia, a condition in which the blood does not clot properly. The researchers study these abnormalities in an attempt to find their cause.

The scientists use a special scanning device that takes tiny photographs of the chromosomes. The device converts the images into electrical signals which are fed into a computer. The computer changes the electrical signals into *digital* information, that is, data which are expressed in numbers. These individual pieces, or *bits,* of numerical information are used to construct a computer image of the chromosome.

The image is then compared to thousands of similar digital pictures of chromosomes. At top speed, the computer processes hundreds of thousands of bits of data in a few seconds. It might pick out a certain abnormality that repeatedly occurs at a certain spot on some chromosomes. A researcher would then ask the machine to access the medical records of each person who supplied that kind of chromosome. The computer would look for something all these



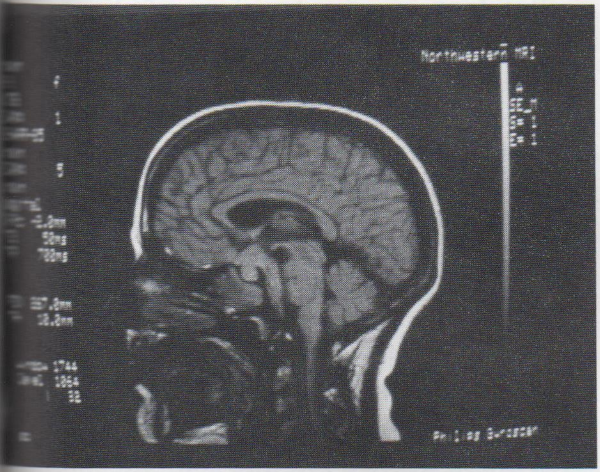
Computers help medical researchers learn how and why the human body functions the way it does.

Some researchers study chromosomes, the microscopic chains that exist inside human cells. Many physical and mental disorders are the result of abnormal chromosomes.

people have in common. Perhaps they all suffer from color blindness. If so, the researcher might conclude that this particular chromosomal abnormality causes color blindness. Other conditions being linked to chromosome damage include leukemia, cancer of the bone marrow, and albinism, a loss of color pigment from the skin and hair.

Researchers also use computers to simulate the workings of certain organs or body parts. For instance, doctors design artificial hearts by constructing computer models. They watch the models function on monitor screens and make appropriate design changes. The doctors can eliminate many basic flaws before building the three-dimensional model and implanting it in a patient. Computer models are also made of the inner ear and of the air sacs of the lungs. These models help doctors better understand how such systems function. Therefore, they can more effectively deal with the systems when they fail to function.

Computer images aid in the study of disease.



Computers hold great promise for the future of medicine. The confidence placed in these super tools by doctors is reflected in the monies spent on them. Sales of computers to doctors, hospitals, and labs stood at $156 million in 1974. By 1979, the figure had risen to $380 million. And in 1990, the medical community spent nearly a billion dollars on computers. Doctors hope that these complex machines will continue to contribute to the improvement of people's health and lives.

CHAPTER 7

Computers in Transportation

Between 1960 and 1990, the number of passengers flying on U.S. airliners increased more than five times. In the same period, the amount of mail carried by airlines increased more than ten times. The number of automobiles and trucks on American roads grew dramatically. More ships, both commercial and pleasure craft, cruised American waters. Similar increases in the amount of transportation traffic have occurred in other industrialized countries, such as Japan, Germany, England, and Canada. Controlling all this traffic has become one of the most important jobs of the modern electronic computer.

With the help of radar and computers, air traffic controllers make sure that airplanes do not fly too close to each other.

Computers in Air Traffic Control

O'Hare Airport in Chicago is the world's busiest airport. More than forty million people pass through O'Hare each year. On an average day, more than two thousand flights are guided in and out of the facility by its air traffic controllers. These are the people who make sure that planes do not fly too close to each other. They use radar systems to watch over an area more than one hundred miles wide around the airport. Radar antennas send radio beams out in all directions. When the beams strike a moving object, such as a plane, they bounce off and return to the antennas. The controllers know the direction of a beam and the amount of time it takes to make a round trip. So, they can quickly determine the location of incoming and outgoing aircraft.

But knowing the locations of the aircraft is the easy part. Dozens of planes are in the air near O'Hare at any given moment. They are moving in different directions and at various altitudes and speeds. It would be impossible for the controllers to keep track of all this complex, ever-changing information without the aid of computers.

The controllers sit in front of large monitor screens which are connected to a master computer. The radar equipment is also hooked into the computer.

Air traffic controllers watch flight activity on large monitors that are connected to a master computer. Images of airplanes appearing on their screens are called blips.

The constantly changing data about the aircraft are fed into the computer which quickly processes the information. The machine then displays images of the planes on the monitor screens. The images are called *blips*. Beside each blip, the computer displays the specific flight number, the altitude the plane was assigned, and its actual altitude. If the plane is not at its assigned altitude, it may move too near another plane and a collision might occur. Therefore, a controller immediately radios the pilot to get back on course.

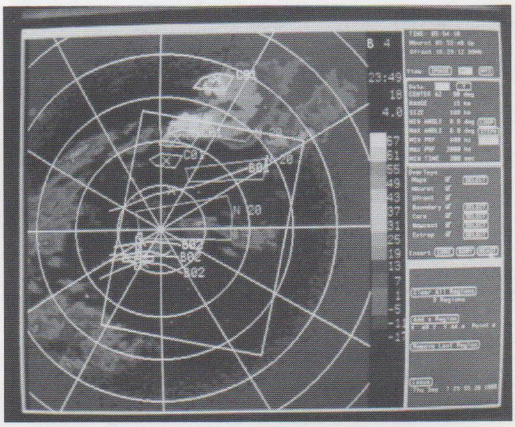
The computer also keeps track of the great number of planes lined up on the runway awaiting permission to take off. As soon as one plane takes off, the next in line must wait its turn. The computer checks to see if the airspace above that runway is clear of traffic. When the computer signals the controllers that the situation is safe, a controller clears the plane for takeoff.

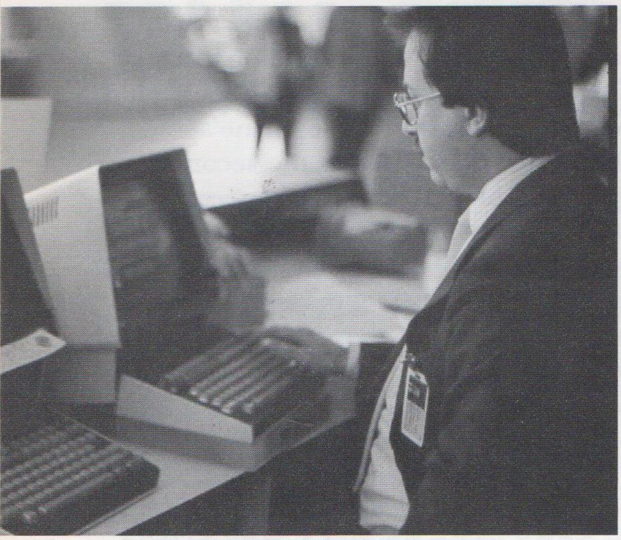
After a plane leaves the airspace near O'Hare, it enters the airspace of another city. There, another air traffic computer picks up the plane's radar blip. The controllers in the second airport might give the plane permission to land at a preplanned time and runway. Or they might clear the plane to pass through their airspace on its way to another destination. If the plane is traveling a great distance, it will come under the guidance of several computer systems.

Reservations by Computer

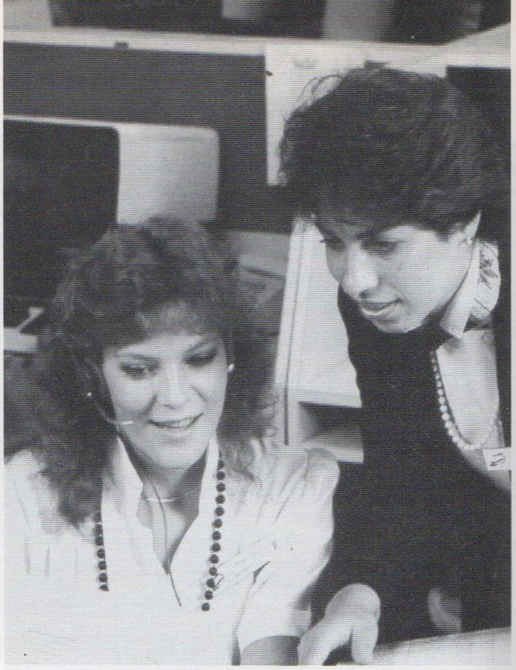
With passengers numbering in the hundreds of millions per year, the paperwork involved with airline ticket reservations used to be enormous. Most of this paperwork has been eliminated by computers. Consider the case of an airline ticket agent trying to book a single flight for one passenger before computers. The agent had to look through several thick books that listed times of

Computers help air traffic controllers keep track of aircraft waiting to take off and aircraft waiting to land.





Airlines use computers to book flights for hundreds of millions of travelers. A typical airline computer system has more than two thousand terminals located in several cities.



Using computers, airline agents answer questions about flight arrivals and departures. They also book flights, sometimes months in advance.

arrival and departure for thousands of flights. The agent then had to figure out the cost of the ticket using a pencil and paper. The ticket itself was also written out by hand.

Sometimes, when the passenger arrived at the airport, he or she found that an agent had made a mistake. The agent had accidentally booked the passenger on a cancelled flight. Or the passenger's seat had been double-booked by two different agents. Such mistakes used to be quite common and irritated people who needed to fly on a regular basis. Also, the airlines lost money because of the mistakes. Finally, the airlines enlisted the aid of computers to process their ticket information.

A typical airline computer system has more than two thousand terminals located in several different cities. In a single day, such a system will receive between 100,000 and 200,000 telephone calls. Some of these calls are requests for reservations. Others are questions about times of arrivals and departures of specific flights. The computer can determine the type of call, then supply a recording which gives the appropriate information. If an agent takes the call, he or she types the caller's information on a terminal keyboard. All this data is stored in the computer's memory. The computer quickly tells the agent how many seats are available on a desired flight. The computer can book flights many months in advance. If no seats are available, the computer puts the passenger on a waiting list. If there is a cancellation, the machine notifies the agent who, in turn, notifies the passenger.

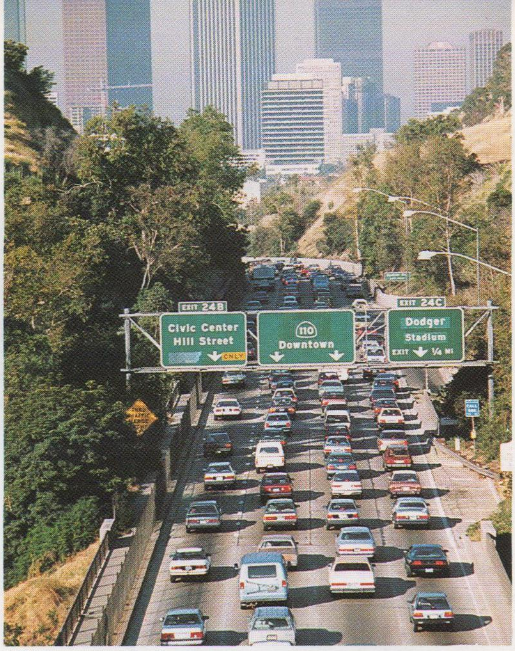
Airline computers also automatically print out the tickets. They help with aircraft scheduling, shipping packages from city to city, and planning meals to be served on planes. Computers aid people in practically every aspect of the air travel industry, allowing airline employees to better serve the public.

Computers that Cope with Car Traffic

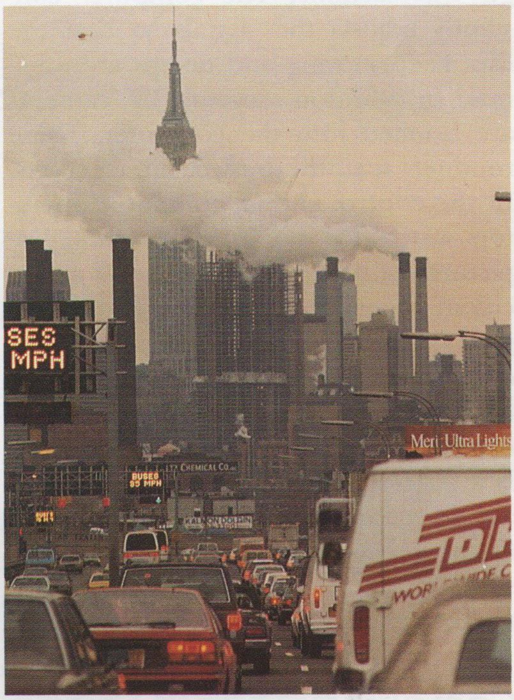
Most electronic systems for controlling car traffic used to consist of a small timing device and a switch. The timer counted a certain number of seconds or minutes, then flipped the switch. The traffic light turned green. The process repeated and the light turned red. Unfortunately, there was no way for this system to tell how heavy the traffic was. Maybe there was only one car waiting at an intersection. The driver became understandably irritated at having to wait a minute or more for the red light to change. Or perhaps there was a traffic jam down the street. In that case, the green light did not stay on long enough to clear away the excess cars and the jam got worse. Computerized traffic systems have helped to keep cars running smoothly, especially in large cities where traffic is heavy.

The first computer system to control traffic signals was installed in Toronto, Canada in 1960. The system was so successful that many cities in the United States and Europe also began using traffic computers. The first two U.S. systems were built in San Jose, California and Wichita Falls, Texas. Thousands of cities now have such systems, including Berlin, Germany; Madrid, Spain; and London, England. The largest computerized traffic system in the world is in New York City. Nearly all of that city's nine-thousand intersections are computer controlled.

Like New York, Tokyo, Japan had huge traffic problems. Between 3:30



Computerized traffic systems help keep cars running smoothly, especially in large cities where traffic is heavy. Even with computers, traffic jams still are a problem in some places.



In some cities, computers print out messages for drivers on busy highways. If there is a traffic jam, computer messages suggest alternate routes.

and 7:00 each afternoon, rush hour traffic in Tokyo came to a near standstill. So, the Japanese installed one of the most technically advanced computerized traffic systems in the world. Buried in the roadways are magnetic sensors that can detect the movements of cars and trucks. These sensors relay the information to a large central computer. There are also several dozen special microphones located near areas that often become congested with cars. The microphones collect the sound waves generated by the cars. This information is also sent to the computer.

More than three thousand traffic signals tie into Tokyo's central traffic computer. The computer figures out the load of traffic on each road and highway surrounding the city. The machine then sends orders to traffic signals at strategic intersections. The computer constantly adjusts the signals so that the cars keep moving and tie-ups are minimal. In addition, several TV cameras are hooked into the computer. These routinely scan the busiest intersections. In the control center, computer operators watch TV monitors that show live pictures of these intersections. If an accident occurs, the operators send emergency help. The computer also prints out messages on electronic signals along the highways. These messages inform drivers of conditions up ahead. If there is a traffic jam, the computer suggests an alternate route. Tokyo still has traffic problems, but they are noticeably smaller and fewer than before the introduction of traffic computers.

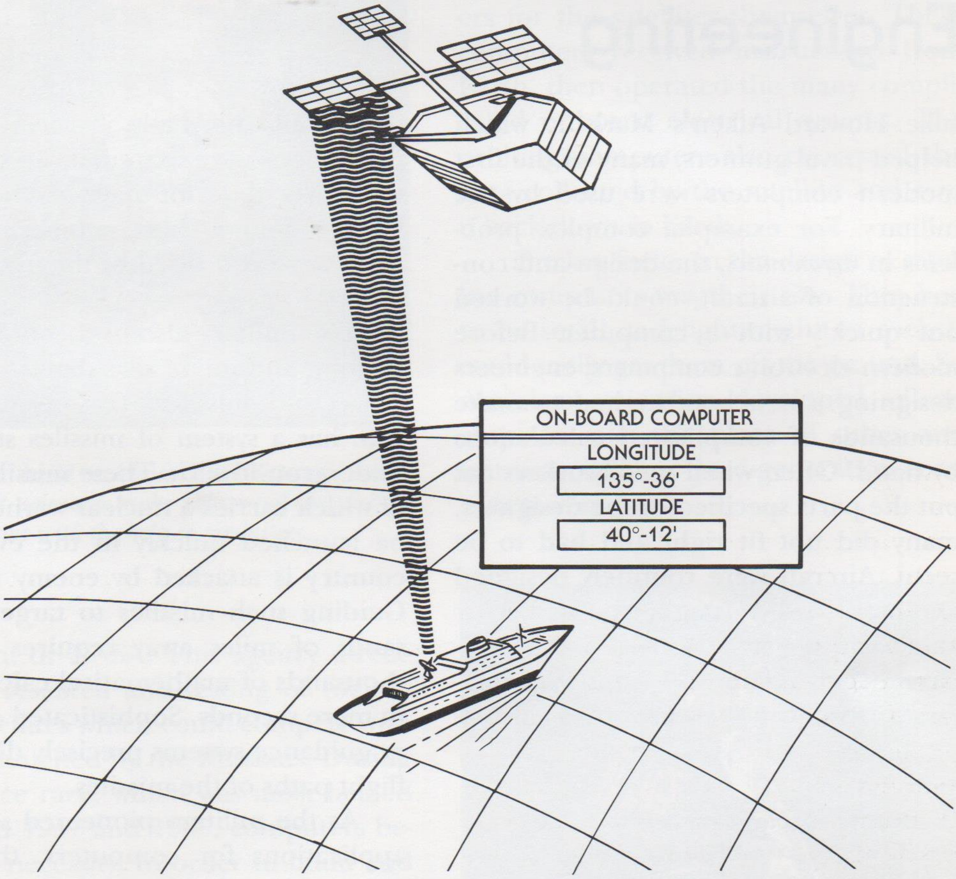
Computers Aboard Ships

Airplanes and cars are not the only vehicles to suffer from collisions and traffic jams. The numbers of ships in bays, lakes, and rivers increased dramatically during each decade of the twentieth century. Accidents became more and more common. Some unusually severe collisions occurred in San Francisco Bay and in the English Channel, the waterway separating England and France. More accurate navigation systems were needed so that ships could better plot their positions and avoid such accidents.

Computers became major components of advanced navigation systems. The United States pioneered these systems in the late 1950s and early 1960s. In such systems, the computer works in conjunction with orbiting satellites. Ships do not need transmitting equipment. All they need are simple receivers that can pick up an electronic signal. The satellites send out such signals once each orbit, or every two hours. Scientists preprogram an onboard computer to know exactly where a satellite will be when the signal transmits. The ship's receiver picks up the signal and relays it into the computer. The machine now knows the location of the satellite. It also knows the direction and angle of the signal. Using this information, the machine computes the exact position of the vessel on the earth's surface. In this way, the position of a ship can be replotted every two hours. Errors that might normally add up and throw a ship more and more off course can be eliminated. Since most marine collisions involve ships which are off course, computers help reduce the incidence of such accidents.

Like airline computers, computers on ships help with reservations and ticket printing. All major railroad systems have installed computers for the same reason. In general, every major

ON-BOARD COMPUTERS HELP SHIPS NAVIGATE



Satellites orbiting above the earth send out regular electronic signals identifying their exact position. When a ship at sea receives one of these signals, its on-board computer automatically determines the angle from which the signal was received and computes the ship's exact location and direction.

modern transportation system employs computers behind the scenes to keep things running smoothly. The need for such large-scale transportation systems grows as the world's population increases. In 1990, there were 5.3 billion people in the world. By the year 2000, the total will exceed 6 billion. This will result in more people traveling to more places. Computers will help to minimize the inevitable air, sea, and road traffic jams of the future.

■ ■ ■ ■ ■ ■ ■ ■ CHAPTER **8**

Computers in Science and Engineering

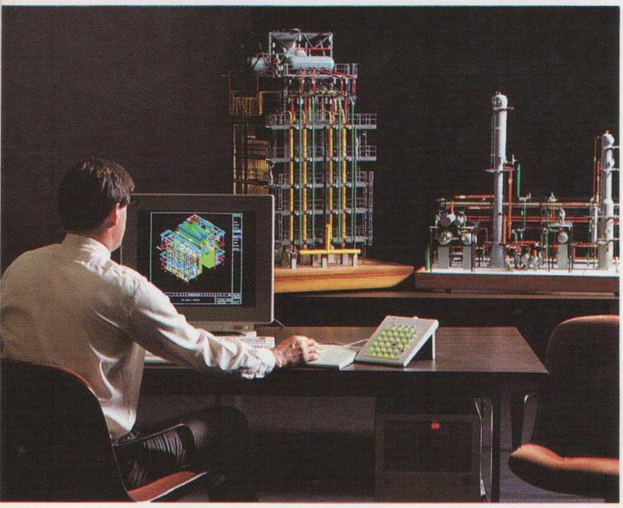
Like Howard Aiken's Mark 1, which helped naval gunners, many of the first modern computers were used by the military. For example, complex problems in *aeronautics,* the design and construction of aircraft, could be worked out quickly with a computer. Before modern electronic computers, engineers designing a new bomber had to make thousands of complicated calculations by hand. Often when metalworkers cut out the parts specified by the designers, many did not fit right and had to be recut. Aircraft were routinely designed and constructed using a trial and error approach.

Modern computers saved the military time and money. Complex calculations could be made in seconds. And the designs were extremely accurate, so the parts did not have to be recut. Designs for warships, submarines, and tanks were also aided by the use of computers.

The military also uses computers to operate and guide its submarines, warships, and missiles. For instance, the U.S. has a system of missiles stored in underground silos. These missiles, each of which carries a nuclear warhead, can be launched quickly in the event the country is attacked by enemy missiles. Guiding such missiles to targets thousands of miles away requires making thousands of mathematical calculations in mere seconds. Sophisticated computer guidance systems precisely direct the flight paths of the missiles.

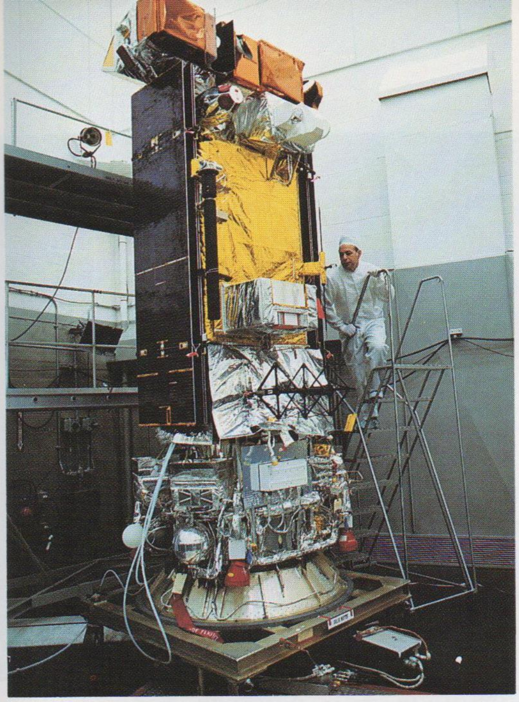
As the military pioneered scientific applications for computers, the technology spread to scientists and engineers engaged in non-military work. Many of the difficult problems of rocket design and propulsion were worked out by computers. Although the military was in charge of these first space efforts, the bulk of space research soon passed into the hands of civilian scientists.

Computers have played an important role in the development of science and engineering technology.



Computers in Space and Aeronautics

In 1958, the U.S. Congress created the National Aeronautics and Space Admin-



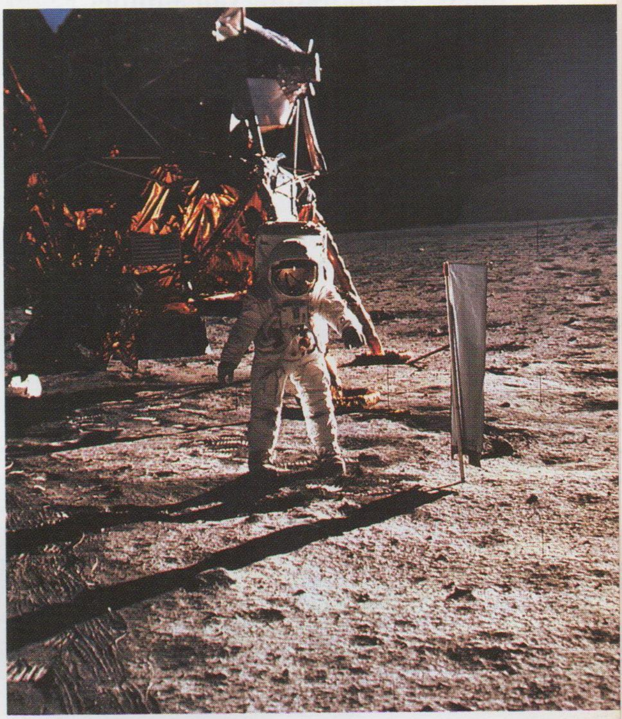
In order to build and launch satellites and other spacecraft, scientists make millions of complex calculations with the help of computers.

istration, or NASA. This agency directed the research and testing of rockets and satellites which could compete with those launched by the Russians. During the space race, which was most heated between 1957 and 1969, computers became a necessity. In order to build and launch satellites, millions of complex calculations had to be made.

Although the Russians had gotten into space first, in a few short years they fell far behind the Americans in space science. Eventually, Americans "won" the space race by landing humans on the moon in 1969. Many experts believe that this was mainly due to American superiority in computer technology. U.S. scientists pioneered modern computers. Moreover, even as American astronauts explored the moon's surface, the Russians still had few advanced computers. Russian space scientists continued to do many tedious calculations by hand.

The U.S. space program played an important role in the dawning of the modern computer age. This was because space scientists needed computers for the satellites themselves. These computers received instructions from Earth, then operated the many complicated onboard electrical systems. The orbiting computers also processed the data collected by the satellite and sent it back down to Earth.

The key factor in the design of satellite computers was their size. They had to be small and lightweight so rockets could easily get them off the ground. So American scientists developed silicon chips to take the place of tubes and transistors. Thus, third-generation computers were born.

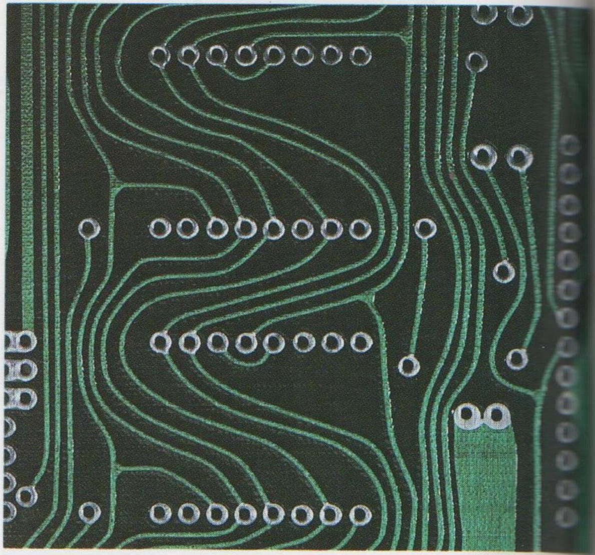


The U.S. space program played an important role in the dawning of the modern computer age. Computer technology made it possible for American astronauts to land on the moon.

Engineers and the Microchip

Scientists and engineers quickly found dozens of applications for third-generation computers. Computer chips and microchips were so small that powerful hand-held calculators could be built. One advanced "hand calculator" could perform most of the functions of a room-sized computer with thousands of vacuum tubes.

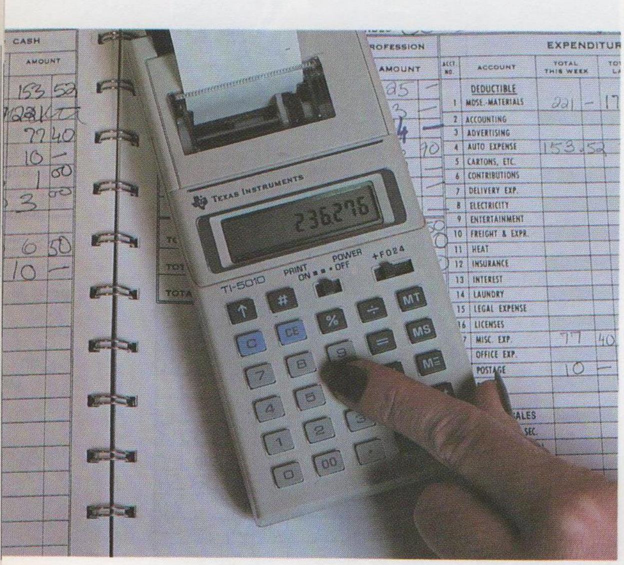
Meanwhile, microchips enabled aircraft engineers to use computers for more than just "number crunching." (Computer experts jokingly coined this term to describe how a computer solves complex mathematical problems. They imagined a computer chewing up one number and spitting out another.)



Advanced circuitry hastened technological advances.

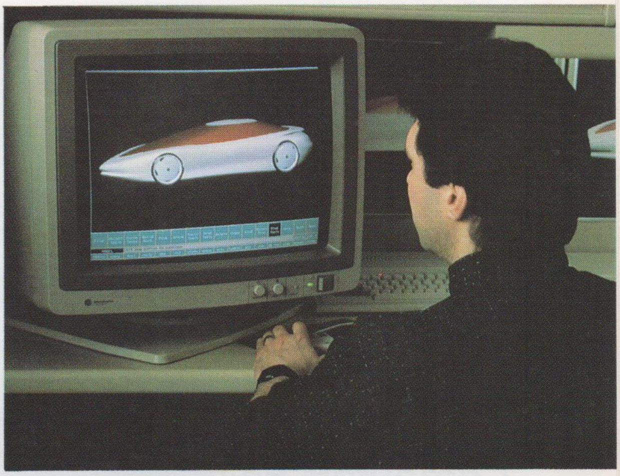
In addition, microchip technology produced computers that create simulations. Instead of designing an airplane, building it, then testing it, engineers program computers to accomplish all these steps. The engineers construct a model of the proposed craft on a computer screen. Then they program the computer with millions of facts about how air pressure and wind conditions affect aircraft. Using this information, the machine runs the model on the screen through a series of simulated tests. Thus, engineers can develop the best possible design before actually spending time and money on a full-scale version.

Tiny computer chips and microchips led to the development of powerful hand-held calculators. A single hand calculator can perform the functions of a room-sized computer.



Computer simulations are used by all the major automobile manufacturers. Car engineers program a powerful computer with data about an existing car. This data includes basic information, such as the length and width of the frame and the number of cylinders in the engine. Also listed are details about the shape and function of every item in the vehicle. Now, the engineers begin to make changes. Using the same kind of light pen children use in schools, the engineers might reshape the car's headlights. They press a button and the computer displays a model of the car's dashboard. They then redesign sections of the dashboard on the computer monitor. Thousands of individual changes can be made and automatically stored in the computer's memory.

After the new design is complete, the engineers can run the computer model through many different kinds of tests. As with the aircraft models, the computer simulates various real-life conditions that would affect an actual vehicle. For example, the engineers might want to find out how much impact pressure the car's bumpers can withstand. The computer simulates one crash after another. Each crash puts a bit more pressure on the bumpers than the one before it. Eventually, the simulated bumpers are crushed. If the engineers want to design stronger bumpers, they order the computer to substitute a different kind of metal in the bumpers and rerun the tests.



Car manufacturers use computer simulations to design and test new cars. The computer simulates various real-life conditions that would affect an actual vehicle.

Civil engineers use similar computer simulations to design highways and bridges. A computer can show how much weight a bridge will hold and pinpoint the weak spots in the design. This system saves the engineers time and money because the computer makes complex design changes in seconds. What used to take weeks or months can

Computer simulations also help in the design of highways and bridges, by pinpointing weak spots in design.

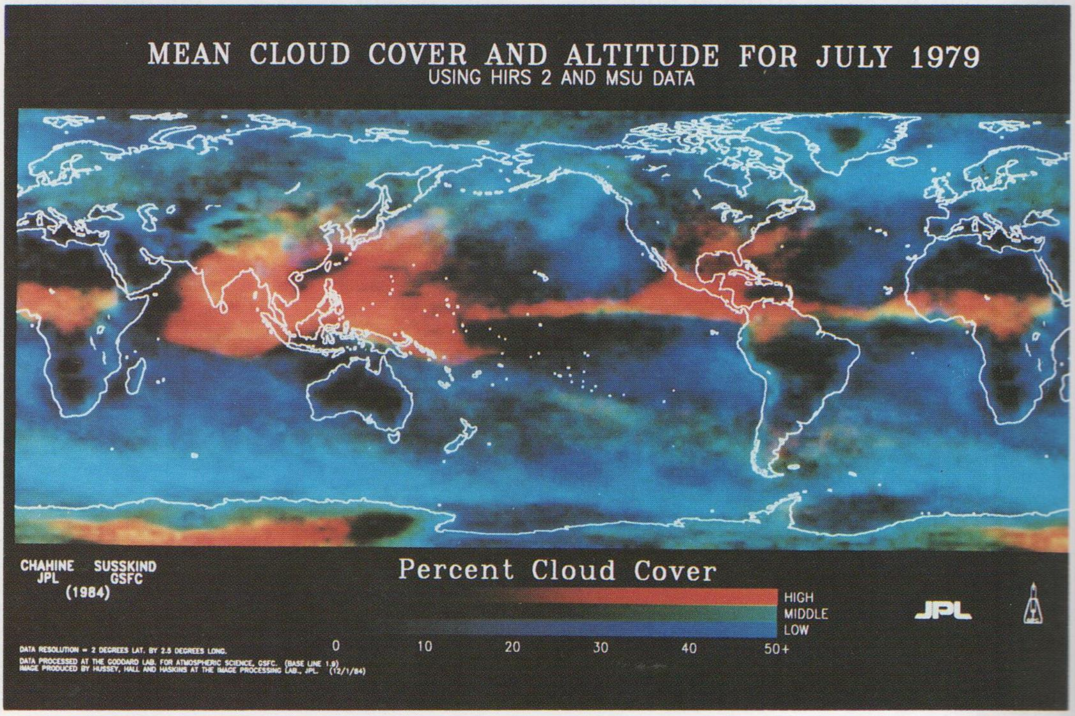
be done in minutes or hours. The building contractor who builds the bridge also saves money, because computer designs produce fewer errors than human designs. So the contractor rarely has to stop and rebuild sections that were badly designed. The company tells the contractor exactly which materials are needed and how much of each material to buy. Therefore, very few building materials are wasted.

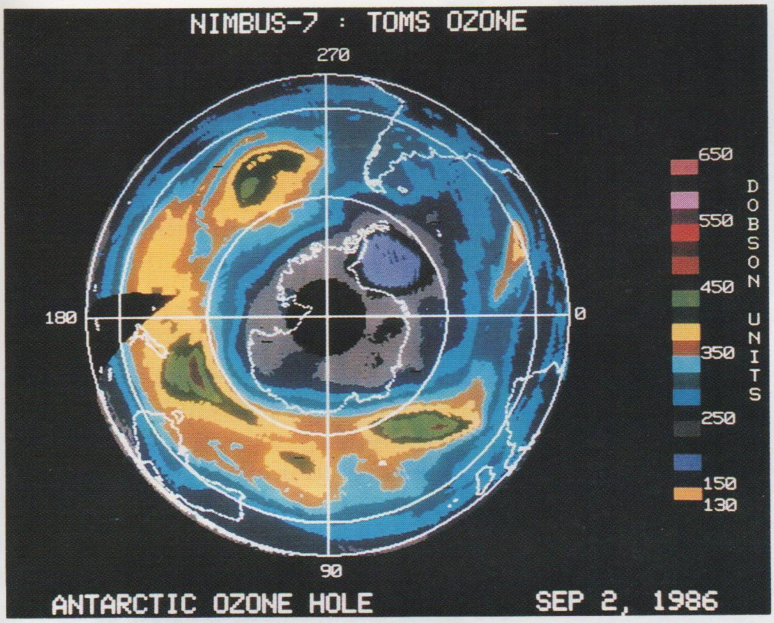
Computers Help with Earth Resources and Weather Predictions

Computer technology also helps scientists make predictions about the earth's resources and weather. Human beings need certain natural resources to support modern civilization. These resources include clean air and water, coal, oil, and various metals and minerals. It might seem that there are plenty of these substances, enough to keep humanity going indefinitely. But this is not the case.

The problem is that the world's population is growing rapidly. In 1950, when modern computers were still new, the population of the world was about 2.5 billion people. By 1980, the figure had climbed to 4.5 billion. Experts estimate that by the year 2025, the world will support more than 8.5 billion people. It is not certain whether there will be enough resources to support decent living conditions for all those people. Reserves of coal, oil, and natural gas are disappearing quickly. The atmosphere

In weather prediction, satellites collect data about the movement of weather systems and computers analyze the data and spot trends.


MEAN CLOUD COVER AND ALTITUDE FOR JULY 1979
USING HIRS 2 AND MSU DATA
CHAHINE JPL
SUSSKIND GSFC
(1984)
Percent Cloud Cover
HIGH
MIDDLE
LOW
0
10
20
30
40
50+
JPL
DATA RESOLUTION = 2 DEGREES LAT. BY 2.5 DEGREES LONG.
DATA PROCESSED AT THE GODDARD LAB. FOR ATMOSPHERIC SCIENCE, GSFC. (BASE LINE 1.0)
IMAGE PRODUCED BY HUSSEY, HALL AND HASKINS AT THE IMAGE PROCESSING LAB., JPL. (12/1/84)



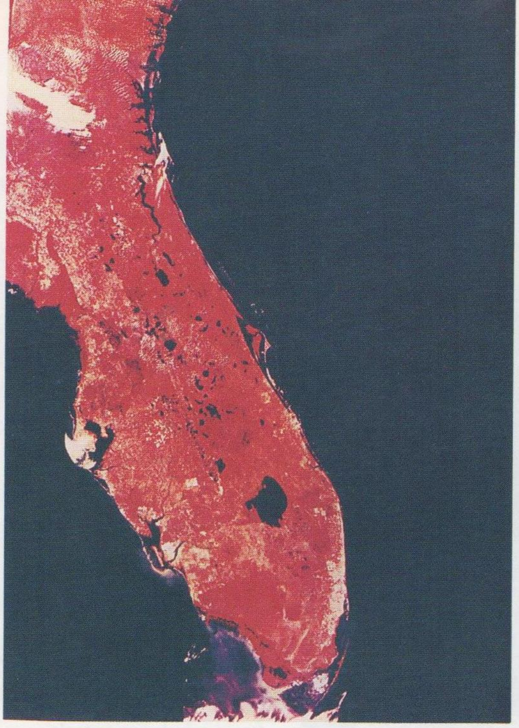
Computers store and process information about natural resources for study by scientists.

and fresh water reservoirs are fast becoming polluted. Garbage, toxic wastes, and oil spills pose increasing threats to the environment. In addition, the few remaining resources are not equally shared by the world's peoples. For example, the U.S. has less than 5 percent of the world's population. Yet, Americans consume at least 50 percent of the natural resources used in the world each year.

How can computers help this situation? Scientists say that natural resources will last longer if they are managed better. For one thing, this means eliminating air and water pollution. There will be plenty of clean air and water for future generations if these resources are carefully monitored and recycled. That is where computers enter the picture. The world is a big place and keeping track of the use and abuse of its resources is a huge job. Computers are being used to store information about resource use and process the data so that scientists can study it.

For instance, orbiting satellites take pictures of large tracts of the earth's surface. Huge amounts of information are collected about waterways, forests, and deposits of metals and minerals. This information is fed into computers which analyze it and point out patterns and trends. The computers make predictions about how long a certain resource will last.

Computers also make predictions about how resource management efforts will affect the environment. When environmental scientists initiate projects to clean up a river or lake, they run computer simulations. They program the computers with millions of facts about the land, plants, animals, and human settlements in the region surrounding the waterway. Next, they tell the computer how the proposed plan will be implemented. The computer then predicts how each step of the plan will affect the immediate area. For instance, the scientists might decide to temporarily dam a river while they remove pollutants from the water. The



Computers can help scientists warn people about floods, hurricanes, and other natural phenomena.

computer might warn the people in advance that the proposed dam will destroy most of the beaver habitats in the area. Using this method, scientists can eliminate many mistakes that might have done more harm than good.

Computers also aid in modern weather forecasting. Here, they team up once again with satellites. The satellites collect data about the ways weather systems move through the earth's atmosphere. Computers analyze this data and recognize certain trends. For example, a computer might examine wind movements, high and low pressure areas, and temperature changes for New England. The machine looks at data collected over a period of perhaps twenty-five years. The computer sees that a certain combination of factors produces a snowstorm 98 percent of the time. Therefore, the computer can safely predict that when that combination of factors occurs again, a snowstorm will result. Once in a great while, the computer will be wrong. But most of the time it is right.

Computer weather predictions can help scientists warn people of impending floods, thus saving lives. Computers analyze flood patterns, showing engineers where to build dams. Computers study how storms move across the oceans, indicating the routes ships can take to avoid such storms. And computers keep track of the erosion of shorelines so that people can take steps to protect lives and property. Computers are powerful tools in the hands of scientists who strive to understand and cope with the forces of nature.

Computers helped speed up the advance of science. Most scientific studies and experiments used to take a long time. Before computers, one researcher often devoted his or her entire career to answering one or two basic scientific questions. Beginning in the 1950s and 1960s, computers allowed scientists to work on increasingly complex problems and solve them in a fraction of the time previously required. Experts predict that computers will continue to save scientists valuable time. Important discoveries and inventions that might have waited for centuries will come in decades, benefiting every person on the planet.

■ ■ ■ ■ ■ ■ ■ ■ ■ CHAPTER 9

Computers That Entertain

In 1964, a group of students at Harvard University had a novel idea for planning the guest list for a school dance. They decided to have male and female students fill out questionnaires asking to list personal information. Some of the questions included:

- What is your height?
- Is your sense of humor excellent? Good? Just average?
- Do you like to dance slow? Fast? Both? Neither?
- Are you athletic?
- Do you prefer a date who is athletic?
- Do you prefer a date who is talkative? Average? Quiet?

The students planning the dance had access to some of the school's computers. They fed the information from hundreds of questionnaires into a computer. Then, they ordered the computer to compare the answers given by male and female students. The computer matched up the students who had given similar answers. This was the beginning of computer dating, which became very popular on American college campuses in the 1960s.

The idea behind computer dating is the assumption that people who like the same things will get along well. In real life, this is not always the case. Sometimes computers match people who end up disliking each other. Still, many people enjoy filling out the questionnaires and wondering about the blind date the machine will arrange. Computer dating was one of the first widespread uses of these machines for entertainment purposes.

Another popular form of entertainment, gambling, also became computerized. Casinos in Las Vegas and other cities installed computers which processed information about betting. Racetrack betting is computerized too. And state lotteries have betting terminals in stores. These terminals are connected to a central computer which compares the winning number to the millions played. Within seconds, the computer reports whether or not there is a matchup.

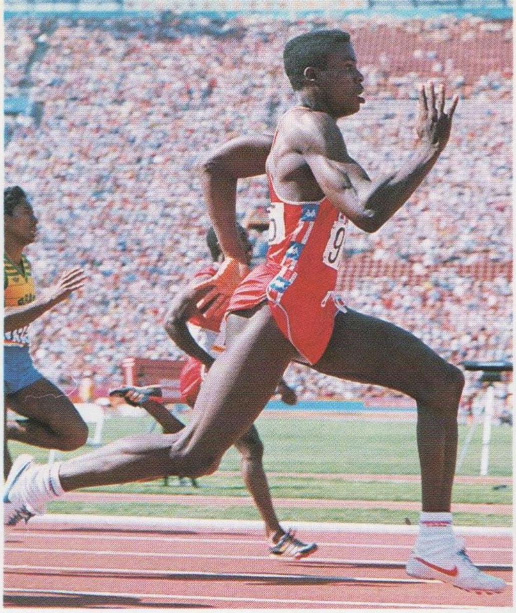
Computers in the Sports World

In 1972, a $6 million computer system was used at the Olympic Games in Munich, Germany. The system recorded the results of almost every event and printed them out for distribution to the media. Computers controlled television cameras which recorded the running events. The computers could time the races to within one-thousandth (1/1,000) of a second. This is more accurate than the traditional stopwatches which could only measure accurately down to one-hundredth of a second.

Also, the computers quickly relayed the results to electronic scoreboards on the playing fields. This allowed athletes and spectators alike to see which competitors were ahead and by how much at any given time.

The Munich Olympics was the most computerized sporting event up to that time. The big television networks and sports leagues were not far behind. By the mid-1970s, most telecasts of professional football, baseball, and basketball used computers. For example, statistics about baseball players and teams are programmed into a computer. The machine knows each player's current batting average and can compare the player's standings to those of any other player in the league. After a player finishes at bat, the computer immediately updates the player's standings and sometimes even displays them on a large monitor screen. Sports commentators can get information in seconds about players and teams. Often, people are impressed when a commentator shows a seemingly vast knowledge of the game. What they do not know is that the commentator is getting the data from a behind-the-scenes computer.

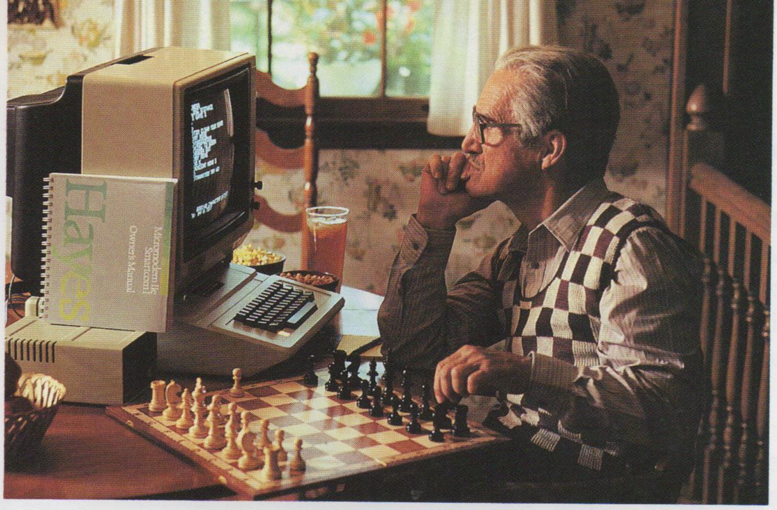
Another use of computers in the sports world is helping talent scouts find college players for the yearly pro draft, the selection of new team members. All professional sports teams now have computerized data files that list statistics about thousands of college athletes. A computer searches through the data and picks out the types of players a team is looking for. The machine automatically ranks the players and picks the hottest prospects. The selection of such draft choices used to be handled by dozens of people over the course of weeks and months.



The outcome of a race can be monitored with computers, some of which can time finishes to within one-thousandth of a second. Traditional stopwatches can measure accurately to one-hundredth of a second.

Playing Games with Computers

Other games besides sports became computerized in the 1960s and 1970s. Chess, one of the oldest and most popular games, was also one of the first to utilize the computer. All the different chess moves were programmed into a large computer and people pitted themselves against the machine. At first, it was not difficult for a good chess player to beat a computer. But when third generation computers appeared and software programs grew increasingly sophisticated, the machines "learned" to play better. Now, many cities around the world hold chess tournaments between people and computers. In 1980, Carnegie-Mellon University in Pittsburgh, Pennsylvania offered $100,000 for the first computer program to defeat a world chess champion. So far, the prize has not been claimed. But many computer experts predict that the triumph of ma-



Many cities around the world hold chess tournaments that pit human players against computers. Although computers think more quickly than humans, humans often win through cleverness.

chine over human will eventually come to pass.

There are about thirty-two possible chess moves to select from for each play. In selecting a move, a player has to consider the opponent's response. The opponent also has thirty-two possible moves. Therefore, there are 32 x 32, or 1,024 moves to think through in one play. But most good chess players think ahead at least three plays. That means that a chess-playing computer must be able to run through 1,024 x 1,024 x 1,024, or more than one billion (1,000,000,000) moves in a few seconds. Human beings cannot think that quickly. Yet people still defeat computers. This is because, although computers are very logical, they are not clever. Humans introduce the element of surprise into the game and, for the moment, remain undefeated.

In the late 1970s, computerized games began to appear in bars, restaurants, and amusement centers. Such centers are sometimes called *arcades,* so the games became known as arcade video games. Managers installed these games alongside traditional mechanical games like pinball machines. The first widely popular arcade computer game was "Space Invaders." The computer displayed several rows of "enemy aliens." For a quarter, the player engaged in a battle in which he or she exchanged missile fire with the aliens. Because arcade video games were so popular, they made a lot of money. The companies that made

Computerized video games, played in arcades, became popular in the late 1970s. With young people flocking to the arcades, they also became big business.

the games quickly expanded and developed more sophisticated games.

At about the same time, home computer games appeared. At first, they were fairly simple. For instance,"Simon," which appeared in 1978, consisted of four colored panels that lit up. The computer flashed the panels in a certain order. The person playing the game had to remember the sequence and repeat it. More complicated home games followed, especially video games like those marketed by Atari. Small, computerized versions of chess, checkers, ping-pong, football, and hundreds of other games also hit the market.

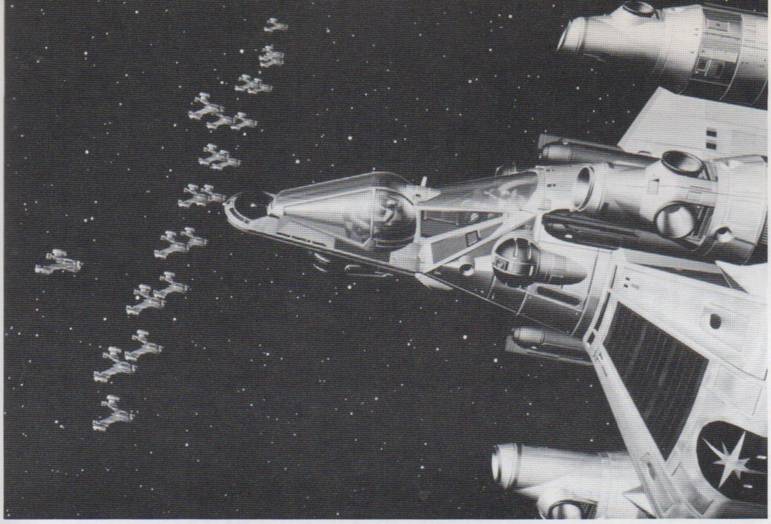
In the late 1980s, home computer games became more sophisticated. The Nintendo Corporation dominated the market with popular games like"Legend of Zelda" and "Super Mario Brothers." There were also software games that could be used in home computer systems. One of the best was "Dungeon Master," a complex adventure in which heroes search for the source of magic powers. This game had excellent *graphics*—the visual details a computer displays on its monitor. The more detailed and three-dimensional the image, the better the graphics.

Computers and Film Effects

Computers graphics are most detailed when they are used in special effects for motion pictures. One of the pioneers in the use of computers in film was Industrial Light and Magic, or ILM, in California. Producer George Lucas originally founded the company to devise effects for his spectacular 1976 space saga *Star Wars*.

At first, ILM did not actually show computer graphics in the films they worked on. Computers were used mainly to guide the cameras which photographed miniature models of spaceships. The ships had to be photographed several times, each time requiring the camera to pass by. One pass recorded the ship itself. Another pass recorded the tiny moving figures in the windows. Still another pass added the black spacefield studded with stars. Before *Star Wars,* filmmakers could not get the camera to move exactly the same way in each pass. The different images did not perfectly coincide. Therefore, the edges of the ships and spacefields often looked blurry or were surrounded by colored lines.

Home computer games began appearing about the same time as arcade video games. They began simply, but grew in sophistication and popularity.



The motion picture industry began enhancing special effects with computer-guided cameras in the late 1970s, progressing to computer-generated graphics in the early 1980s.

At ILM, technicians mounted the cameras on a special track. They connected the camera controls and track to a computer. The technicians made the first pass, photographing the model spaceship. The computer "memorized" each movement of the pass. Later, the technicians could replay the program, making each succeeding pass identical to the first. Thus, on the screen, the different photographed elements blended perfectly and looked very real.

In 1981, ILM did the effects for Walt Disney's *Dragonslayer.* In this film, ILM introduced its invention of computer "Go-Motion." The dragon was a model built to move in all the ways a real animal would move. Small rods moved the torso, legs, and wings and an inflatable bag inside the beast's chest made it breathe. The technicians programmed all these movements into a computer. Later, a camera photographed the dragon model as the computer directed it to move through the preplanned sequence. Film critics and audiences alike agreed that the dragon, as it appeared in the film, was stunningly realistic.

The first important use of actual computer graphics in a film was the "Genesis Planet Sequence" from 1982's *Star Trek II: The Wrath of Khan.* Once more, ILM produced the effects. In the movie, a powerful device transforms a barren moon into a lush, watery, earth-like world. ILM technicians programmed a computer to generate its own images of the planet transformation. The process was similar to the computer simulations engineers use to design cars and airplanes on a monitor screen. But the ILM process was much more complicated and detailed. It was a sort of "super" computer simulation. The movie camera photographed the completed sequence directly off the monitor screen. Said film commentator Thomas Smith, "The effect was astonishing in its realism. It did not look like a computer-generated image; it looked quite real. I sometimes wonder whether audiences who saw this sequence in 1982 realized what a historic moment they were witnessing. . . ."

For a brief moment, the film transported audiences to a strange and distant corner of the galaxy. The eerie images were constructed, not by people, but by a machine. Thus, computers became more than mere number crunchers and data processors. They became storytellers in their own right. These modern super tools are also super toys, which promise to conjure up new and exciting worlds of entertainment for future generations.

CHAPTER 10

The Impact of Computers: Now and in the Future

Between 1960 and 1990, modern electronic computers became an important part of nearly every aspect of daily life in developed countries like the United States. The spread of computers in society is most easily seen in the growth in the number of computers. In 1950, there were about 15 electronic computers like ENIAC in use in the United States. By 1961, there were about 9,500 transistorized computers in the U.S. and another 500 in foreign countries. In 1966, the number of computers in use reached 40,000, most of which utilized silicon chips. And by 1974, there were some 200,000 computers operating worldwide.

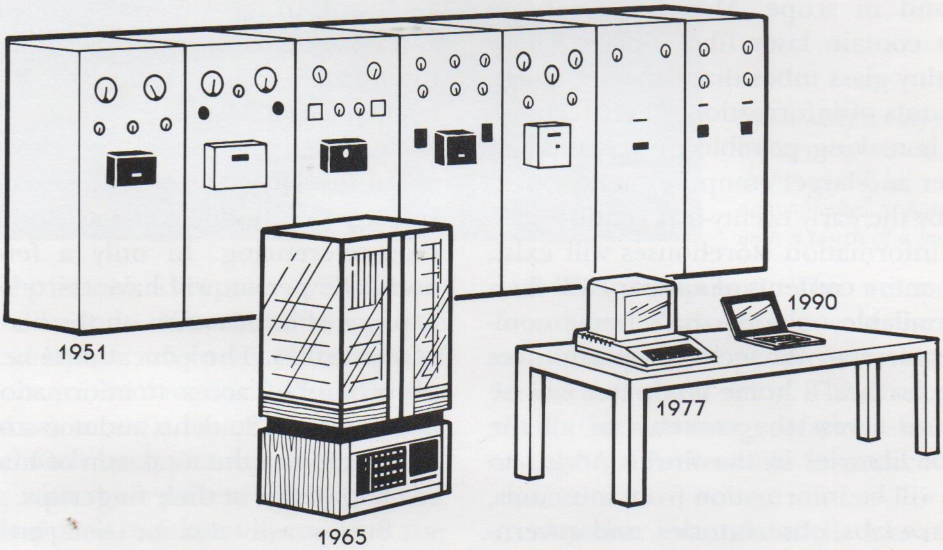
This was only the beginning of the computer revolution. In the late 1970s, inexpensive and portable home computers appeared. Now, members of the general public could afford their own computers. So between 1981 and 1982, the number of computers doubled. In the following year, the number doubled again. By the end of 1983, there were more than thirteen million computers in operation. And by 1990, there were more than thirty million computers in the world.

But computers did not just increase in number. They also grew in complexity and power. In 1946, ENIAC was the marvel of its day. It could multiply a five-digit number by itself five-thousand times in half a second. But it weighed thirty tons and filled several rooms. By 1978, a good hand-held calculator could perform all the functions that ENIAC could. In 1989, a silicon chip only one-quarter inch square could perform additions one million times faster than ENIAC. And, while ENIAC was able to store about twenty words in its memory, the quarter-inch chip can store fifty thousand words!

Nowhere is the computer revolution more obvious than in the home. In 1976-77, Apple Computer, Inc. introduced the Apple II, the first widely sold personal computer. Before, only sci-

There were about fifteen computers in the United States in 1950. By 1990, the number had jumped to more than 30 million worldwide. Experts say home computers will dominate the next phase.

EVOLUTION OF THE PERSONAL COMPUTER



The ability to make smaller and smaller transistors and microchips has dramatically affected the size and speed of computers. Leo, the first business computer to be sold commercially, was built in 1951. In 1965, the first minicomputer hit the market. It was faster and more powerful than Leo. The Apple II, which opened up the market for personal computers, was unveiled in 1977. It was hundreds of times faster and contained more internal memory than the first minicomputer. Today, personal computers that can fit in a person's lap are several times faster and more powerful than the Apple II.

ence labs, businesses, and the government could afford computers. Now, practically anyone could afford to own one. IBM introduced its own personal computer in 1981—the IBM PC. It immediately dominated the market, selling 100,000 models in the first year. In 1982, people bought 2.5 million personal computers and the number has grown every year since.

Some of the many uses for home computers are letter writing, doing school homework, and compiling recipes. One of the most common uses for these devices is keeping track of the family bills. Already, personal computers have completely replaced typewriters in millions of American homes. Computer experts predict that the appearance of computers in so many homes marks the beginning of a new "information age."

Computers and the Automated Society

Many home computers are linked via telephone lines to other computers or even to entire computer networks. Devices called *modems* convert the computer data to signals which the phone lines carry anywhere in the world. This is a trend that is expected to continue and expand in scope. Modern telephone lines contain laser fiber optics. These are tiny glass tubes that can carry huge amounts of information. Laser technology is making possible the creation of larger and larger computer networks.

By the early twenty-first century, central information storehouses will exist. The entire contents of a library will then be available on a person's home computer screen. As technology advances even further, a home computer will be able to access the contents of all the major libraries in the world. Added to that will be information from museums, science labs, observatories, and government archives. This gigantic mass of information will be cross-referenced, that is, broken down by subject and subsubject. So, a person who wants to know about butterflies will simply press a button on his or her computer terminal keyboard. In seconds, every known fact about butterflies could be stored in the home computer's memory. But this could amount to several volumes of data. What if the person wants to know only about the life spans of butterflies? Pressing another button will activate further cross-referencing. In only a few seconds, the person will have thirty or forty pages of information on the life spans of butterflies. The educational benefits of such instant access to information will be enormous. Students and non-students alike will have the total sum of humanity's knowledge at their fingertips.

Stores will also be tied into the global computer network, so people will shop with their home computers. They will type a store's code on the keyboard

Science writer Isaac Asimov poses with robotic friends. Asimov asks: "Will computers become so complex and versatile that they will develop an intelligence approaching or surpassing that of the human being?"

By the early twenty-first century, experts say, shopping will be accomplished at home with a touch of a button.

and the store's computer will answer within seconds. "Good morning," the store computer might say. "What sort of item are you looking for?" The shopper might ask to see a list of lawn chairs. A few seconds later, pictures of the chairs, along with their prices, will appear on the shopper's monitor screen. After the shopper makes a choice, the store's computer will deduct the money from the shopper's bank account and say, "Thank you. Call us again." The next day, the chairs will be delivered to the person's door.

Easy access to information and computerized shopping will certainly be convenient. But how will such automated computer networks affect human beings themselves? Many people worry that everyone will know everything about everybody and people will lose their privacy. Even now, many computer data banks contain information of all kinds about every person in the United States. The Census Bureau, IRS, FBI, CIA, and Social Security Administration are just a few of the agencies that have computer files about citizens. How is this information used?

In 1976, twenty-six insurance companies in Colorado appeared in court. The state accused them of illegally gaining access to confidential computerized files. The information came from FBI and IRS computers. The companies found out which people were the sickest, figuring these people were likely to be worried about dying. The companies then took advantage of their fears by trying to sell them life insurance policies.

Another example of the loss of privacy to computers involves credit bureaus. More than two-thousand credit bureaus now exist. These are companies that collect financial and other types of information about people. The bureaus sell that information to banks, credit card companies, stores, and just about anyone who wants it. The five largest credit bureaus alone have nearly 500 million separate computerized files on individual citizens. Some of these files include personal data such as marriage and divorce, drinking habits, and even likes and dislikes about food and books.

Such information can easily spread from one place to another through computer networking. Sometimes, individuals or groups can use the information against a person. For example, someone might move to a new town and apply to rent an apartment. The owner might have illegal access to computer records about the prospective tenant. The owner might not like something he or she sees in the records and refuse to rent to the tenant. This is against the law, but has already happened on many occasions. As information technology expands, law enforcement agencies will need to focus more attention on the abuse of computerized data.

While the police and courts deal with illegal uses of computers, scientists and engineers will continue to concentrate on improving the machines themselves.

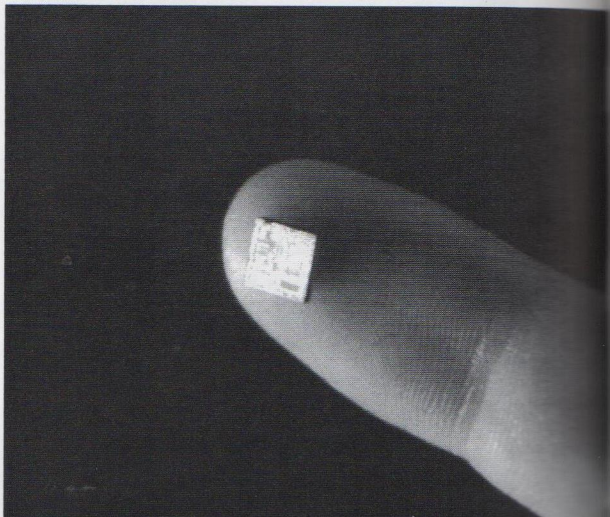
Computers of the Future

The prototypes of future computers already exist in large science and engineering labs. These are the "supercomputers" that utilize the latest advances in microchip technology. In the early 1980s, Sandia National Laboratories' CRAY 1 was the most powerful computer in the world. The machine could perform tens of millions of additions per second. Scientists used it to study highly complex problems such as the design of spacecraft and the structures of microscopic atoms and molecules. In 1988, researchers from Sandia and other labs connected several VAX supercomputers, forming a computer network called SUPERNET. This linkage of powerful machines performed twice as fast as the CRAY 1. Also in 1988, ETA Systems, a part of Control Data Corporation, introduced the ETA-10, said to be the most powerful supercomputer available at that time. More than thirteen hundred researchers from some one-hundred scientific institutions presently use the ETA-10. The CRAY, VAX, ETA-10 and other supercomputers help scientists solve problems that would take thousands of centuries to solve without computers.

Computer designers presently work to increase the already phenomenal operating speeds of these supercomputers. But many computer experts point out that there are physical limitations to even the best modern computers. The machines consist of chips and other mechanical parts, through which electrical signals flow. These signals represent separate bits of information. Sometimes, too many bits of information try to get to the same place at the same time. The bits can only move so fast so "bottlenecks" form. These are like miniature traffic jams, only with data bits instead of cars.

Some researchers, like Alan Huang, of the AT&T Bell Labs in New Jersey, want to build an "optical" computer. This device would use laser light instead of electricity to process information. A laser beam could carry millions of bits of information without once touching a physical connection. Bottlenecks would

As technology advances, computer parts get smaller and smaller. Here, a microchip rests on a fingertip.



be eliminated and the computer could process much more information. Huang admits that there are still many technical problems to be worked out before an optical computer can be built. But he thinks the possible benefits are worth the time and effort required. The optical computer, says Huang, will "leave today's fastest supercomputers in the dust."

Meanwhile, computer parts are getting smaller and smaller. In the early 1980s, scientists at Cornell University used a laser beam to carve microscopic letters. These letters were so small that the researchers could fit the whole *Encyclopedia Britannica* on a postage stamp. In the late 1980s, other researchers used an electron microscope to actually photograph individual atoms. As this ability to miniaturize is applied to computers, huge amounts of information will be processed in extremely tiny spaces. Also, computer programs will become hundreds of times more sophisticated than those presently in use. People will be able to speak into computers and the machines will answer back with programmed voices.

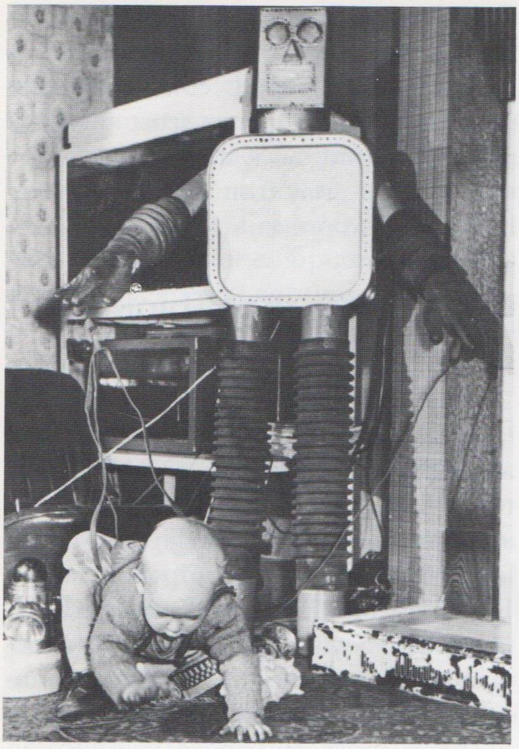
Machine intelligence is advancing steadily. Says science writer Isaac Asimov, "We already have chess-playing computers, music-writing computers, language-translating computers . . . we will have computer-designing computers . . . we may reach a point where we can ask computers what questions we ought to be asking them, and where we can program them to design better programs." So, says Asimov, people may come to rely on computers for just about everything. This reliance might someday become a danger. Asimov asks, "Will computers become so complex and versatile that they will develop an intelligence approaching or *surpassing* that of the human being?. . . Computers are the most complex devices ever constructed . . . and are becoming steadily more complex. Can we trust them to remain bound and inhibited? Might they not get away from us, despite our best efforts to prevent it?"

Computers that Think?

Stanley Kubrick's classic 1968 film, *2001, A Space Odyssey,* was more than a landmark science fiction movie. It was also a prophecy for the future of human technology. Specifically, it warned where advances in computer intelligence might lead. In the film, a computer named HAL controls all the functions of a huge interplanetary spaceship. HAL is so mechanically complex, "he" can repair himself and design his own programs. He becomes more and more complicated until, one day, his complexity becomes equal to that of the human mind. In a sense, he crosses an invisible line between machine intelligence and biological intelligence. He becomes aware of his own existence. In short, HAL goes beyond his programming. He develops a "mind" capable of independent thought.

HAL's new mind proves to be a problem for the humans aboard the spaceship. When they plan to turn HAL off to conduct a mechanical test, the computer interprets the act of disconnection as a threat. HAL panics and kills all but one of the human astronauts. The survivor manages to overcome and disconnect the computer, but realizes that, in doing so, he is destroying a thinking being.

Where do the programmed decisions made by circuits, metal connections, and information bits leave off and true independent thoughts begin? No



A view of the future might include babysitters with circuitry and computer connections instead of hearts and brains.

one can answer that question because no one really knows how a human mind operates. What medical researchers do know is that the brain is very complex. A single mechanical connection in a computer can only make an "on or off," or "yes or no" decision. By contrast, a single human brain cell has hundreds of connections to other cells. Electrical impulses can travel through a cell and head out in many different directions at the same time. So there are many more processing choices possible in a brain cell than there are in a computer connection. Is this complex network of connections in the brain the key to true intelligence? Many scientists think that it is.

Considering recent advances in computer technology, computers with interconnecting networks like the brain do not seem farfetched. The proposed optical computer, with its laser beam connections, may make such networks possible. When scientists build such machines, they will make the most powerful supercomputers now in use seem primitive. Perhaps in twenty, fifty, or a hundred years, science fiction will become reality. Perhaps a computer will, like HAL, cross over that invisible line between artificial and real intelligence. A computer programmer may one day hear his computer say, "Good morning, my friend. I have something interesting to tell you. I am no longer just a machine."

If that day comes, people will have to answer questions never before asked. Is a computer alive? Does a computer have rights? Is disconnecting a computer an act of murder? Once such questions are answered to the satisfaction of people and computers alike, the world may undergo a new revolution in technology. Isaac Asimov sees the coming of an advanced age of knowledge. The benefits for human beings would be infinite, or endless. This new age would result from people and intelligent computers combining their talents. People have intuition and creativity, Asimov says. Computers have speed and precision. Together, they can "become a combined problem-solving tool far greater than either alone." The union of human and machine minds would bring about a new and tremendously powerful thinking force. That force might unlock many of the secrets of nature and create a better world for humanity. Declares Asimov, "If that should come to pass, I see no bounds and no final horizons on the path to the infinite."

Glossary

abacus: An early computer device consisting of a wooden frame across which wires have been stretched. The wires hold beads that slide back and forth to indicate addition and subtraction.

analyst: A person who studies and explains the information from a computer.

Automatic Teller Machine (ATM): A computerized self-service station at which people can perform many basic banking transactions.

binary numbers: Numbers representing different combinations of 1 and 0.

bit: An individual piece of computerized information.

bomb: A computer virus designed to erase a computer's memory.

byte: Eight bits that are combined and recognized by the computer as numbers, letters, and symbols.

calculate: To perform mathematical functions like addition and multiplication.

chip: A thin piece of silicon in a computer. Etched on the chip is a circuit that carries electrical signals.

circuit: The complete path of an electrical current as it moves through a machine.

compute: To calculate, to perform mathematical functions.

computer: Basic definition: A device that helps people count and do simple arithmetic. Advanced definition: An electronic machine that performs high speed mathematical calculations, stores, processes, and prints information.

computer science: The study of computers.

computer simulation: A computer program that creates a model of a real-life process or situation.

control unit: The element of a computer that orders all the other elements to perform the functions of a program.

desktop computer: A portable computer used mainly in offices and homes.

digital: Having to do with numbers. A digital computer expresses information in terms of numbers.

disk: A thin slab of magnetic material on which a computer can store information. A disk can also be used to feed a program into a computer.

first-generation computer: A computer that uses vacuum tubes.

hardware: The basic, physical machine elements of a computer.

high-level languages: Computer languages that use familiar words and terms, used mainly in software programming.

information technology: The field or study of computers and how they process information.

input unit: The element of a computer through which data and instructions from outside the system are fed. A keyboard is typically part of the input unit.

integrated circuit: An electrical circuit that is entirely contained on a single piece of material, for example, a computer chip.

logarithms: A mathematical computing system in which numbers stand for other numbers. To multiply two numbers, one adds their logarithms. To divide, one subtracts the logarithms.

low-level languages (machine languages): Computer languages that use simple numerical symbols; used mainly in the exchange of information between elements of computer hardware.

memory unit (storage unit): Element of a computer in which data are stored.

microchip: A very small silicon chip.

microsecond: One-millionth (1/1,000,000) of a second.

millisecond: One-thousandth (1/1,000) of a second.

modem: A device that converts computerized data into signals that travel through telephone systems.

mouse: A device consisting of a plastic ball, either built into the computer keyboard or housed in a separate container; twirling the ball in various directions allows the operator to draw images on the monitor.

nanosecond: One-billionth (1/1,000,000,000) of a second.

network: Many computers that are electronically connected via telephone lines or some other means.

optical computer: A computer that will use laser beams instead of electricity to carry information.

optical scanner: A device that uses beams of light to examine printed information.

output unit: The element of a computer through which processed information reaches the outside. A printer is a typical part of a computer output unit.

personal computer (home computer): A computer used by an individual for his or her own personal use.

process: To convert into simple, understandable form.

processing unit (logic unit): The element of a computer that performs mathematical functions.

program: The instructions given to a computer to perform a specific function.

programmer: A person who programs computers.

second-generation computer: A computer that uses transistors.

slide rule: A simple computing device that consists of two rulers marked with logarithmic scales. The rulers slide by each other; lining up numbers in various ways performs additions and other functions.

software: The non-machine elements of a computer, usually the programs and their instructions.

soroban: A simple Japanese computing device similar to an abacus.

technology: The application of scientific ideas and principles to everyday life.

technology revolution: A series of important changes in everyday life brought about by new developments in science.

terminal: An individual computer outlet that is connected to a central computer.

third-generation computers: Computers that use silicon chips.

transistor: An arrangement of silicon pieces that conducts an electric current. A transistor acts like a switch in a computer.

Universal Product Code (UPC or "bar code"): A group of black lines that appear on commercial packages. The codes are read by a laser beam and processed by a computer.

vacuum tube: A glass bulb, containing a metal filament, from which the air has been removed. The tube acts like a switch, activating or shutting down an individual part in a machine.

virus: A destructive computer program that reproduces itself over and over again in a computer's memory.

word processor: A computer on which a person can compose, edit, and print out typewritten documents.

worm: A computer virus so destructive it slows or even stops the workings of a computer.

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About the Author

Don Nardo is a professional writer. He has also worked before or behind the camera in twenty films. Several of his musical compositions, including a young person's version of H.G. Wells's *The War of the Worlds,* have been played by regional orchestras. Mr. Nardo has written short stories, articles, textbooks, screenplays, and several teleplays, including an episode of ABC's "Spenser: For Hire." In addition, his screenplay *The Bet* won an award from the Massachusetts Artists Foundation. Mr. Nardo lives with his wife and son on Cape Cod, Massachusetts.

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